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Conference of Remote Sensing Educators (CORSE - 78)

A workshop held at Stanford University
by NASA Ames Research Center
Moffett Field, California
June 26-30, 1978

NASA

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CONFERENCE COLLABORATORS

Ames Research Center
American Society of Photogrammetry
Association of American Geographers
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PREFACE

The National Aeronautics and Space Administration has organized a nationwide Regional Applications Program to transfer NASA technology to user agencies. The Western Regional Applications Program (WRAP), covering the fourteen western states, has established a program to cooperate with colleges and universities in the WRAP states in increasing and enhancing the teaching of remote sensing technology to enrolled students, faculty members, and user groups.

As a part of this effort, a Conference of Remote Sensing Educators (CORSE-78) was convened to stimulate communication among faculty members and NASA, and to encourage exchange of class materials, curricula, course outlines, and ideas for teaching remote sensing. Two days of formal papers led off the Conference, followed by three days of workshops organized around regional interests, data acquisition and reduction methods, audiovisual and multimedia techniques, and discipline interests.

Speakers and workshop panel members were invited from universities within the WRAP states and were asked to speak on assigned subjects relating to problems associated with remote sensing curriculum design, teaching methods and equipment, facilities, and texts. Also covered were the attributes of a well-trained remote sensing technician and technologist, problems in introducing new remote sensing courses, and multidepartmental approaches to teaching remote sensing.

The proceedings have been reproduced from manuscripts submitted by the participants and are intended to document the topics discussed at the workshop. A list of attendees is included in the appendix. Suggestions for a possible CORSE-80 are solicited. Send comments to CORSE-80 Chairman, NASA Ames Research Center, Mail Stop 240-7, Moffett Field, CA 94035.

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Clarence A. Syvertson, Director
NASA Ames Research Center

As you know, this Conference is sponsored by the NASA Ames Research Center and hosted by the Stanford School of Earth Sciences. Our two organizations are operating in collaboration with the U.S. Geological Survey, their EROS Program, the Association of American Geographers, and the American Society of Photogrammetry. There is an important message in my mind in the number of organizations involved. When the weather and communication satellites came into being, there were ready-made constituencies: the weather service and the communications industry, respectively. When the new technology was provided, all that was necessary was to find a new way to do something we'd been doing for years, only now in a new and better way. The field of remote sensing is not always so simple. The users of the information are much more varied and diffuse: researchers, several federal agencies, state and local government organizations in a variety of disciplines, and several elements of private industry. With all of these different interests involved, maybe your curriculum should include courses in political science. I think of times in the past when we could have used some of that training. The technology is also changing rapidly. NASA, for one, is planning expanded programs in both sensor development and in data processing, and new flight programs are also being planned. To me, all of these considerations combine to indicate the importance of education in the field of remote sensing, and accordingly, the importance of this Conference. The coming week is a full one. You will hear from people in many fields representing many different organizations. The Ames Research Center is very happy to be one of the participants, and I hope you find the Conference productive. Thank you very much.

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PROBLEM STATEMENT

Conference of Remote Sensing Educations (CORSE-78)

by

Robin I. Welch
CORSE-78 Chairman

Introduction

Why is a Conference of Remote Sensing Educators being held?

We feel that it's an idea whose time has come. The Conference grew out of problems and frustrations that were revealed when the Western Regional Applications Program (WRAP) was initiated. WRAP is a NASA program initiated in 1977 to enhance and expand the utilization of NASA technology by civil users--primarily state agencies.

We discovered early in that effort that there is a rapidly expanding demand for training in remote sensing technology from three groups of people--resource managers and technicians in government and industry, regularly enrolled students in colleges and universities, and faculty members in those institutions.

It was also apparent that every student taking a job in the earth and environmental sciences who did not have adequate training in remote sensing while he was in college would be a potential trainee in future remote sensing continuing education courses. By postulating and projecting this deficiency into future years, it was obvious that NASA would never be able to get ahead of the problem because the government through the RAP effort could not possibly train all of the potential users because their numbers would be increasing faster than they could be trained with proposed training budgets and schedules.

In addition, we saw an absence of communication on remote sensing matters among many of the faculty members, both within and among colleges, who have an interest in teaching and doing research in remote sensing. Such a situation precludes the development of common teaching standards, course requirements and student-achievement objectives by the various academic institutions, assuming such standards are desirable.

And finally, there is a large volume of processed, high quality satellite and supporting aircraft data that is known to be useful that is not presently being used.

Methods

In order to address these problems, NASA organized a Regional Applications Program (RAP) covering all 50 states (see Figure 1), designed to transfer NASA technology to users through short courses, technical assistance and cooperation in demonstration projects. The Western Regional Applications Program (WRAP) covers 14 western states, and through WRAP a project was initiated to involve colleges and universities in achieving the objectives of the program through cooperation in training and technical assistance.

The objectives of the cooperative university project were suggested in order to increase and improve the teaching of remote sensing at colleges and universities through the following methods:

1. Include in every course in earth science and environmental subjects at least a minimum introduction to remote sensing technology and applications covering the advantages, limitations and processes of the subject.

2. Provide courses in applied remote sensing technology subjects in the various earth science, environmental and urban

disciplines for those students who desire advanced training in the field. These courses should include appropriate basic subjects such as characteristics of the electromagnetic spectrum; remote sensing system physics, geometry and chemistry; matter and energy relationships; vehicles, camera and sensor systems; and data analysis, photo interpretation systems and methods.

3. Educate appropriate faculty members in the technical and operational aspects of remote sensing to equip them to fill the need to train students and users.

4. Provide continuing education courses in appropriate remote sensing and supporting technology subjects.

5. Encourage the interaction of faculties in dealing with remote sensing educational matters through such functions as CORSE-78, university advisory committees, direct face-to-face efforts, exchange of materials and products, and sharing of facilities.

6. Define how NASA and other governmental agencies can serve and cooperate with the academic community in utilizing and teaching remote sensing technology.

7. Develop appropriate standards of course work, curriculum, exercises and experience for students and to prepare faculties to teach remote sensing.

8. Organize a Remote Sensing Science Council to interact with NASA in establishing cooperation with universities, in defining goals and objectives, and in conducting courses.

9. Cooperate with NASA in developing applications and training programs for future satellite systems, i.e., Landsat-III and D, Seasat, Nimbus-G, Shuttle, etc.

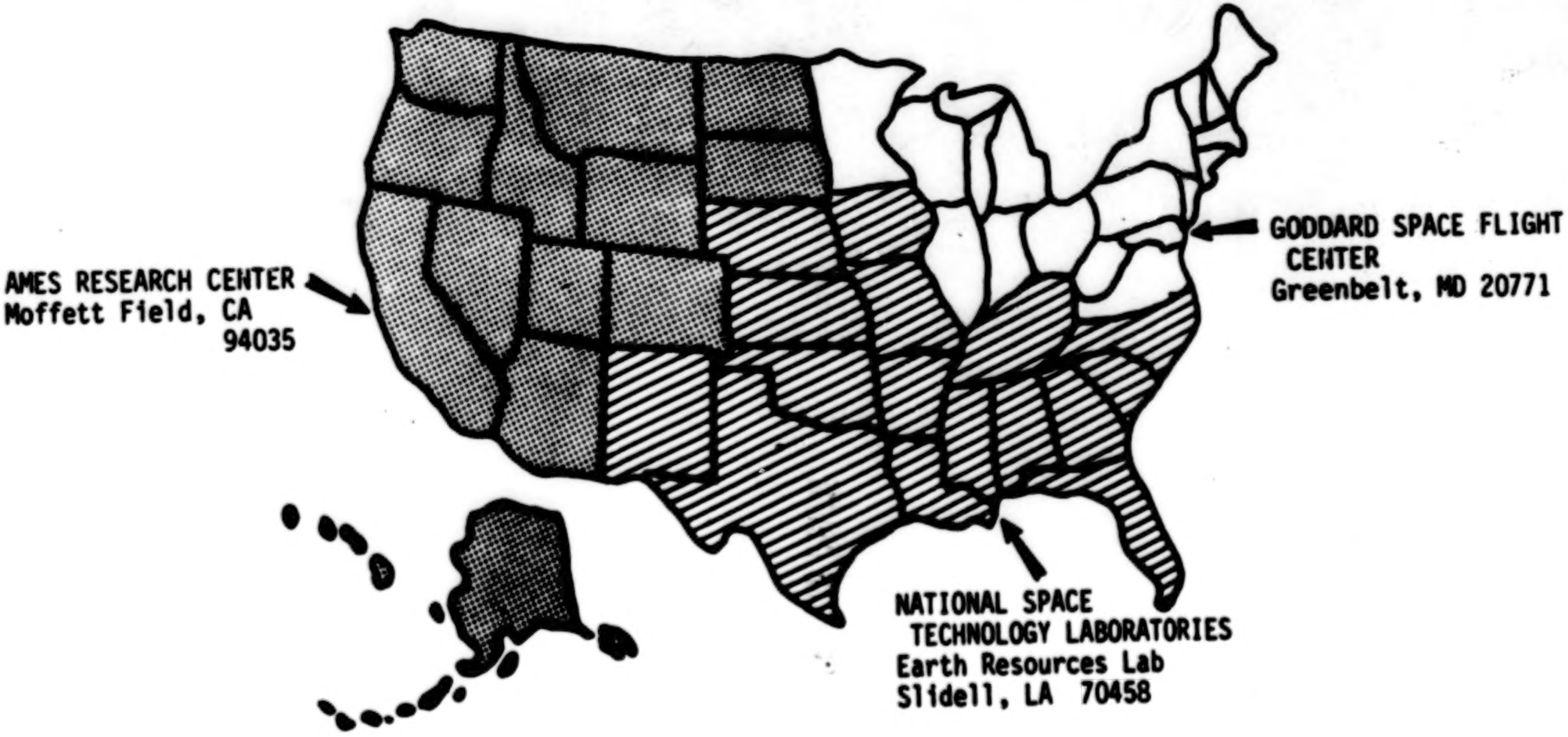
CORSE-78 Objectives and Agenda

The objectives of CORSE-78 (Conference of Remote Sensing Educators - 1978) are to enhance and expand the teaching of remote sensing in WRAP colleges and universities. The Conference presents two days of formal papers and three days of workshops. It is anticipated that needs and plans for faculty training courses will be discussed and tentatively scheduled from data generated at CORSE-78.

The question of future conferences (CORSE-80, etc.) will not be decided until the results and value of CORSE-78 are assessed. Therefore, it is vital that all discussions and suggestions for remote sensing educational activities be realistic, frank, in-depth, sincere and to the point for use by NASA and others in furthering the program.

Some of the needs of faculties in remote sensing training have already been expressed to NASA,and WRAP efforts are being directed by such information. We cannot promise any easy solutions, but we are all in this together and through cooperative efforts, regular feedback and sharing of experiences, class materials, products, etc., we will be able to make significant progress in meeting our goals.

REGIONAL APPLICATIONS PROGRAM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NATIONAL SPACE
TECHNOLOGY LABORATORIES
Earth Resources Lab
Slidell, LA 70458

Figure 1

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FORMAL PAPERS

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HISTORY AND FUTURE

OF

REMOTE SENSING TECHNOLOGY AND EDUCATION

By

ROBERT N. COLWELL
Professor of Forestry and Associate Director Space Sciences Laboratory
University of California;
Director, Berkeley Office, Earth Satellite Corporation

INTRODUCTION

A primary objective of this conference as set forth by its conveners is to "enhance and encourage the teaching of remote sensing" so that, in the future, mankind will be better equipped "for meeting the challenge of human survival on earth and for exploring the universe." The question might be raised as to the relevance, within this framework, of a paper dealing, as mine does, with the history, present status and future potential of remote sensing. In answer, we submit the following: By first providing a rather comprehensive description of the many events that have brought remote sensing to its present status, we will be better able, not only to forecast future progress, but also to suggest some of the more fruitful activities that should be undertaken, especially in the area of education and training, in order to maximize that progress. An indication as to the validity of such a procedure was provided well over a century ago by Abraham Lincoln when he said (although in quite a different context, of course), "If we better knew where we are and whither we are trending, we would better know what to do and how to do it."

Pursuant to the above objective and in conformity with the instructions given by the NASA sponsors of the present conference, this paper is divided into the following five main parts: (1) A historical review of the discovery and development of photography and related sciences; (2) Remote sensing progress during the past quarter century; (3) The role of education to date in the development of remote sensing technology; (4) A discussion of some prescribed remote sensing-related questions; and (5) The probable future of remote sensing technology and training. Before we enter into this five-part discussion, however, we would do well to define a few terms for the reason that the science of remote sensing recently has developed more rapidly than the terminology needed to describe it.

As one indication of how rapidly the field of remote sensing has been developing in recent years, we find that those who are working in various aspects of this field do not fully agree on a definition for even the basic term "remote sensing" itself. All of them would no doubt agree, however, that remote sensing pertains to the acquiring of information through the use of aerial cameras and other sensing devices that are situated at a distance (i.e., "remotely") from the objects or features of interest. Furthermore, most of them would agree that, for purposes of the present conference, we should attempt to narrow this very broad definition. Therefore, let us acknowledge that, within the context of both the NASA Western Regional Applications Program and the overall NASA Earth Resources Survey Program, most of the objects or features of interest to remote sensing scientists are those associated with such natural resources as timber, forage, soils, water, minerals, agricultural crops, fish, wildlife, and recreational resources. Consequently, let us be sure that the present discourse, including this preliminary defining of terms, reflects such interests.

Since the term "photography" literally pertains to the product obtained when we "write with light" it might at first seem that the much older term "photographic reconnaissance" would have sufficed without our having needed to invent such an exotic term as "remote sensing." However, the former term in its strictest meaning pertains only to the images obtained when sensing for visible light, i.e., wavelengths that are perceptible to the human eye.

It is, indeed, true that over the years progressively less distinction has been made between that which could literally be regarded as photography and that which superficially looks like photography but is formed with energy from non-visible bands of the spectrum. As a case in point, it was roughly four decades ago that Walter Clark of Eastman Kodak Company published the first edition of his very popular and authoritative book "Photography by Infrared" (Ref. 1). Since "photography" is commonly regarded as the record obtained with visible light and since "infrared" literally means "beyond the (visible) red," there would seem to be a serious contradiction of terms even in that brief title. However, partly through the wide acceptance of that book and its title, a progressively more liberal yet less well defined concept has since developed regarding the outer limits of "photography." Those who recognize the desirability of drawing such limits have quite properly insisted that the more inclusive term "remote sensing" be used to replace the roughly corresponding term "photo reconnaissance" whenever activities that employ other than visible wavelengths of energy are involved. Furthermore they are commendably consistent in arguing that the related terms "imagery", "image analysis" and "image analyst" be used instead of "photography", "photo interpretation" and "photo interpreter" whenever use is being made of any wavelengths of energy outside the visible part of the spectrum.

Generally speaking we will accede to this viewpoint in the present paper while at the same time acknowledging the fact that images obtained at wavelengths that are only slightly longer than the visible red have become known as "infrared photography" and that images taken at wavelengths that are only slightly shorter than the visible violet are termed "ultraviolet photography." Let us be sure, however, that we don't make our uncertainties regarding terminology into bigger problems than they are. Well over 90 percent of the seeming ambiguities with which we are confronted have arisen with the advent of a capability for obtaining photo-like images in the thermal infrared and microwave bands. Whatever problems are generated by this capability in terms of the scope of this remote sensing conference are well worth living with and overcoming so that these important new sensing systems and their products can be adequately understood and fully exploited.

I. HISTORICAL REVIEW OF THE DISCOVERY AND DEVELOPMENT OF PHOTOGRAPHY AND RELATED SCIENCES

Since the technology of modern remote sensing probably would not have been developed without the prior development of photography itself, this section will begin with an account of events which led to the discovery and development of the basic science of photography. As the account proceeds, the development of aerial photography, including color and infrared photography, will be traced. The section will conclude with a documenting of some of the events that occurred during World War II and shortly thereafter, setting the stage for a later section that deals with remote sensing progress during the past quarter of a century.

Perhaps the best accounts from which to draw historical material on photography are those found in three manuals that have recently been published by the American Society of Photogrammetry, viz., the Manual of Photographic Interpretation, the Manual of Photogrammetry, and the Manual of Remote Sensing (Refs. 2,3,4), all of which wereprepared and published under the auspices of the American Society of Photogrammetry. Other valuable accounts have been written by Ives (Ref. 5), McCamy (Ref. 6), Land (Ref. 7), Kohler and Howell (Ref. 8), Katz (Ref. 9), and by Colwell, Slater, and Yost (Ref. 10). The following historical account is based partly on these and several other references. However, a unique emphasis is given here--one which seeks to relate these events specifically to the development of modern remote sensing technology and thereby to the development of our ability for meeting the previously mentioned "challenge of human survival."

A. Observations of our Progenitor, the Cave Man

The first human to engage in remote sensing (in the broadest usage of that term) was, of course, the cave man. We can visualize him now, as he picked up his club, strode from his cave and a few moments later crouched high in a tree or stood atop a ridge. There he strained his eyes, his ears, and his nostrils in an effort to "sense" the presence of an animal that might either constitute a supply of fresh meat for him or be seeking to convert him into a supply of fresh meat for itself. In either event, remote sensing has been a pretty serious business, ever since.

B. Observations by Ancient Philosophers

Even in Aristotle's time (384-323 B.C.) it was known that sunlight is indispensable to life. The ancients knew that sunlight is necessary for the formation of green coloring matter in plants, that it bleaches and corrodes, and that it changes the colors of certain objects. Aristotle, himself, philosophized at length on the nature of light. Johann Heinrich Schulze (1687-1744), a physician of Halle, first demonstrated the sensitivity to light of certain chemical compounds. In 1727 Schulze produced true photographic images by writing on the outside of a glass filled with a mixture of white chalk and silver nitrate. The images soon faded; but Schulze was only a step from the invention of photography. The step proved to be a long and difficult one, and photographs were not made in a camera until more than a hundred years after Schulze's discovery of "light-writing."

The work of Schulze was continued by the famous English potter, Josiah Wedgewood (1771-1804). In 1802 Wedgewood succeeded in copying transparent and opaque pictures on glass and paper coated with silver salts; the images were not permanent, however.

The light sensitivity of several substances, chiefly silver compounds, having been demonstrated by the experiments of Schulze, Wedgewood and others, photographs soon were being made in the camera obscura.

C. Development of the Camera Obscura

Several of the ancient philosophers, including Aristotle, understood the principle of the camera obscura: light passing through a small aperture in a dark box or chamber can be made to form pictures. Ibn al-Haitam (or Alhazen), an Arab scholar of the eleventh century, and the Hebrew scholar Levi ben Gerson (d. 1344) recorded accounts of pinhole cameras used for observing eclipses. Ibn al-Haitam revived and proved Aristotle's theory that vision is created by the agency of light rays.

Roger Bacon (1214-1294) is sometimes erroneously credited with inventing the camera obscura. Actually, the manuscripts of Leonardo da Vinci (1452-1519) contain the first clear description of the process of projecting images through a small opening into a darkened room. In 1553 Johann B. Porta improved the camera obscura by using concave mirrors; in 1558 Daniel Barbara added a biconvex lens. For upward projection, the monk John Zahr developed, in 1665, a portable camera obscura having lens tubes and slanting reversible mirrors like those of a modern reflex camera.

In 1646 the Jesuit Athanins Kircher (1601-1680) described how landscape drawing can be accomplished through use of the camera obscura. Others who experimented with and improved the camera obscura were Johannes Kepler (1571-1630), Robert Boyle (1627-1691), Robert Hooke (1635-1703), William H. Wollaston (1766-1828), and George B. Airy (1801-1892).

D. The First Practical Photography

Joseph Nicephore Niepce (1765-1833) and Louis Jacques Mande Daguerre (1787-1851) are now agreed upon as being the co-inventors of the first practical means of photography. They learned of each other's work through

Charles Chevalier (1804-1859), and agreed to collaborate. Fixing the exposed image, or making it resistant to further light action was the greatest difficulty to be overcome. To do this, it was necessary to remove, without damaging the picture, that part of the light-sensitive chemical which had not been affected by exposure. Herschel's 1819 discovery of sodium thiosulphate ("hypo") was not known to Daguerre until 1839. On August 19, 1839, Daguerre, in reporting on the work which he and Niepce had done, announced their invention of the "daguerreotype." The invention was promptly bought by the French government.

The first reference to the application of photography in making topographic maps was about 1840, when Arago, Director of the Paris Observatory, referred to the Daguerreotype process before members of the Chamber of Deputies, and advocated the use of photography for topographic purposes. In 1849, Colonel Aime Lausedat, an officer in the French Corps of Engineers, embarked upon an exhaustive program to prove that photography could be used to advantage in the preparation of topographic maps.

E. The Talbotype Process for Making Prints from a Negative

In 1841 William Henry Fox Talbot (1800-1877) accidentally discovered that an image formed on paper coated with silver iodide, though barely visible, could be developed or strengthened with gallic acid and silver nitrate. He used waxed, transparent paper negatives, fixed in hypo, to make positive copies on silver chloride paper. First called "Calotype" and later "Talbotype," the pictures made in this way did not have the brilliancy and sharpness of the daguerreotypes. However, the Talbotype process made it possible to produce any number of positive copies from the negative. Talbot's Pencil Nature, published in 1844, was the first book to be illustrated with photographs.

F. The Early Development of Image Enhancement Techniques

Photography as known today would not be possible without a means of amplification or enhancement of the initial action of light. The credit for discovering this phenomenon lies with both Daguerre and Talbot.

The announcement of a practical method of "painting" a picture by the agency of light naturally excited the imagination of everyone and stimulated many investigators to inquire into the phenomenon. One such investigator was Scott Archer, who in 1851 prepared a suspension of silver chloride in nitrocellulose and coated it on glass. It had the advantage over Talbot's in that it was more sensitive and produced better definition than was possible on paper negatives although it required immediate processing. Dr. Richard Leech Maddox rescued the process in 1870 when he eliminated the problem of having to process the material immediately after exposure. He described a gelatin emulsion of silver halide that protected the invisible image for later development.

A silver halide emulsion is naturally sensitive only to blue light (and shorter wavelengths), but in 1873 Herman Vogel discovered that the emulsion could be sensitized to record longer wavelengths by introducing certain dyes to it. As a result, in the ensuing decades new dyes were found and ortho, panchromatic and infrared plates and films were developed.

In 1889 a film base of nitrocellulose which retained the clarity of glass plates, eliminated their fragility, and reduced their bulk and weight was developed by George Eastman. With this increased flexibility the design of smaller, less complex equipment became possible. In addition to this the highly advantageous mechanical properties of a clear, flexible film support were recognized and proved to be of utmost importance in enlarging the areas of application of photography.

G. Developments in Optics

The science of optics is old. It originally covered the phenomena associated with light (visible radiation) and vision. Then, as new discoveries were made, the field of optics expanded to include invisible radiation such as ultraviolet and infrared. Joseph Fraunhofer (1787-1826) and Louis Pierre Guinand (1748-1824) were the first to produce large pieces of optical glass without striae. Frederick Voigtlander produced fast lenses in 1841 based on the 1840 calculations of Joseph Petzval (1807-1891). These lenses were used for portraits as well as landscapes. Other important developments in photographic optics are:

(1) The "distortion free" symmetrical double objective lens system invented by Carl August Steinheil in 1865, and his calculation in 1866 of the distortion-corrected and color-corrected "aplanat."

(2) The establishment in Jena of the large technical glass laboratory of Schott and Gnossen in 1886.

(3) The calculation by Paul Rudolph in 1889 of nonsymmetrical lenses known as "anastigmats" with sharply defined images, and their perfection in 1890 by the firm of Carl Zeiss, Jena.

(4) The construction of the first double anastigmats in 1892 by the firm of C.P. Goerz, in Berlin.

H. Developments in Camera Design

The steady improvement of lenses, combined with the development of more sensitive photographic emulsions, brought about rapid changes in the design of the camera. A compact portable camera, the first to have folding bellows, was described in 1840 by Baron Pierre Armand Seguier (1803-1876). Following in 1860, Thomas Sutton (1819-1875) patented the first mirror-reflex box camera. The Goerz-Anschutz camera with focal-plane shutter appeared in 1890. A little over a decade later, in 1901, Fritz Kricheldorff made the first folding mirror-reflex camera.

The development of the panoramic camera received its impetus primarily from requirements of aerial reconnaissance. Porro in the 1860's developed a camera which employed the panoramic principle and Chevalier developed the photographic plane table in 1868.

I. First Attempts in the Development of Aerial Photography

The first known suggestion for the taking of aerial photography (from a balloon) appeared as a joke in a French lithographed caricature, "Daguerreotypomania," in 1840. In 1858, the photographer Gaspard Felix Tournachon (later known as "Nadar"), planning to produce a topographic map from photographs, ascended in a captive balloon several hundred meters in order to take bird's eye photographs of Paris. He succeeded in photographing the village of Petit Bicetre. In this photograph the houses could be clearly seen. Col. Aime Laussedat followed, later in the same year, with an experiment involving a glass-plate camera supported by several kites.

The first successful photographs to be taken from captive balloons in the United States were made in 1860 by Samuel A. King and J. W. Black from a height of about 400 meters over Boston. During the Civil War captive balloons were reportedly employed to obtain information about the surrounding country and the position of the enemy. Through the services of balloonists

La Montaine and Allon, confederate positions were photographed for General McClellan. The Union Army again utilized aerial photographs, in June, 1862, to gather intelligence on the defenses of Richmond, according to some authorities. Others, however, (Ref. 4) deny that aerial photos were used in the Civil War.

In 1862 and 1863, the physicists Glaisher, Comwell, and Negretti took aerial photographs from balloons over England. Using gelatin dry plates Triboulet in 1879 took for the first time photographs from a free balloon about 500 meters over Paris. A year later, Desmarets obtained excellent negatives at a height of about 1200 meters over Paris using gelatin silver bromide plates. Shadbolt and Dale in England, in 1883, and Silberer in Vienna, in 1885, made further experiments with aerial photography from balloons.

The use of kites as aerial camera platforms was furthered by an English meteorologist, E. D. Archibald, in 1882. In 1889 Russian experimenters connected seven unmanned kites, mounted a camera on each, and sent the assembly aloft to obtain "panoramic" photography which proved to be useful both for cartographic purposes and for the interpretation of features in remotely situated areas.

The use of birds as aerial camera platforms was first engaged in successfully at about the turn of the century. A photographic enthusiast by the name of Julius Neubronner is credited with having designed and patented in 1903 a breast-mounted aerial camera for carrier pigeons. It weighed only 70 grams and took negatives 38 mm square. Through the use of a built-in timing mechanism exposures were automatically made at 30-second intervals.

In about 1900, a captain in the Austrian Army, Theodor Scheimpflug, attached an eight-lens camera to the basket of a balloon. By grouping seven oblique lenses around one vertical one he reportedly obtained complete coverage of the area visible from the air camera station.

J. Development of a Navigable Platform

Before aerial photography could become an integral part of the technique of the earth sciences, a navigable platform for the aerial camera had to be provided. The balloon, pigeon, and kite platforms were not navigable in the strict sense of the word, although many excellent photographs were taken from them. The development of dirigible balloons offered an opportunity for taking photographs from planned positions not possible with captive or free balloons. The piloted aircraft can carry a camera to any part of the earth, as long as the airways are politically unobstructed. Without the piloted aircraft, there would have been little advancement of aerial photography.

Wilbur Wright is credited with having obtained the first photographs from an airplane when on April 24, 1909, he took motion pictures over Centocelli, Italy. Shortly after this, German aviation students training in English flying schools, began to use cameras on advanced training flights.

The first photography known to be used for mapping from an airplane was described by Captain Tardivo in 1913 in a paper presented at a meeting of the International Society of Photogrammetry held in Vienna.

K. World War I and After

Aerial photography of a practical nature dates from the early days of World War I. The first aerial photographs of German-held territory were made by Lieutenant Laws of the R.A.F. Almost overnight, the importance of aerial photographic reconnaissance was recognized, and vigorous efforts were made in France and Britain to provide the military with photographic equipment and to develop proper methods of photography, processing and photo interpretation.

By the end of 1915 Lt. Col. J.T.C. Moore Brabazon, later chief of the R.A.F. photographic section, in collaboration with Thornton Pickard Ltd., had designed and produced the first practical aerial camera. Improved models of this camera thoroughly convinced the military authorities of the value of aerial reconnaissance and photo interpretation.

During the 1920's, (and largely because of developments during World War I), there were many advocates throughout the world for the use of aerial photos for various civil purposes. For example, there were foresters in the United States, Canada, Germany, India, and Burma who saw clearly the multifarious uses of aerial photos in forestry as an aid in the construction of planimetric and topographic maps, in the appraisal of timber and other forest resources, and in planning the location of logging roads, sawmills, landings, and camps. To the Canadian and German foresters goes much of the credit for the development during that period of the basic concepts upon which many of the present day forestry uses of aerial photographs are founded.

Despite considerable photogrammetric experimentation in the 1920's and the publication of many enthusiastic articles which pointed out the indisputable advantages of using aerial photographs in many different ways, it was not until the middle of the 1930's that the extensive use of aerial photographs came about. (This historical fact is worthy of note by those who bemoan the slow rate at which modern remote sensing technology is being adopted by resource managers, despite the publication of many enthusiastic articles which point out the indisputable advantages to their using such technology.) Then it seemed as though all the seeds of enthusiasm which had been planted by aerial photogrammetrists in seemingly barren soil during the previous 10 or 15 years sprouted at once. In the United States all federal mapping agencies including the Geological Survey, Coast and Geodetic Survey, Forest Service, Armed Forces and Production and Marketing Administration were soon making extensive use of aerial photographs. In Canada foresters led the way during this period and surpassed American foresters in their early adoption of photogrammetric techniques for making timber inventories of large areas.

During the mid-thirties there was one major factor responsible for the greatly increased use of aerial photographs in the United States. It was the fact that, for the first time, aerial photographic prints of virtually all parts of the United States were made generally available to the layman at reasonable cost. For most of this area anyone could secure black-and-white (panchromatic minus-blue) prints of existing 9"x9" photography from the appropriate agency of the U.S. government at a cost of approximately 50 cents per print. The ground area covered by a single print commonly was 9 square miles, at a scale of 1/20,000. The resolution of this photography was adequate for most resource inventory purposes. Expressed in terms of what has since become known as "Ground Resolved Distance," the resolution was approximately 5 feet.

During this same period there was a very substantial growth of commercial aerial survey companies.

L. World War II and After

The stimulus given during World War II for more and better aerial photography can scarcely be over emphasized. In 1938, the Chief of the German General Staff, General Werner von Fritsch, made a prophetic and highly accurate statement: "The nation with the best photo reconnaissance will win the next war." Many improvements which photo interpreters now enjoy in the quality of photographic images are attributable to wartime developments in aerial photographic equipment and techniques. During and immediately after World War II intensive military research succeeded in developing cameras with fast and nearly distortion-free lenses, fast and dependable shutters, mountings which absorb aircraft vibration and stabilize the camera against changes in the attitude of the aircraft, and film drive mechanisms which partly compensate for image blur due to the forward motion of the aircraft. The sensitivity of film emulsions was steadily improved and,as described below, special types of film were developed for high sensitivity in certain parts of the spectrum. Drift meters, view finders, and electronic navigation aids, invented during World War II, soon were helping the civilian pilot to navigate his flight lines so as to maintain the required forward and side lap. Military aircraft such as the B-17 "Flying Fortress" and P-38 "Lightning," modified in wartime for photo reconnaissance, were bought and extensively used after the war by commercial photographic agencies.

The amount and quality of available imagery changed significantly within the next few years. Further scientific advancements in lens design and manufacture were made, resulting in a greatly improved ability to form imagery. In addition improved photographic emulsions and new sensors capable of recording many wavelengths of energy other than those comprising the visible spectrum were developed. Contrast manipulation and/or color printing techniques began to be used extensively to exaggerate the subtle differences in radiation that may occur in virtually any part of the electromagnetic spectrum. Some of these developments are dealt with in more detail in the following paragraphs.

M. The Development of Infrared Photography

Sir William Herschel, the great British astronomer, discovered the infrared part of the spectrum in 1800. He passed a thermometer through the extension of a visible spectrum made by a prism and found that beyond the red end the temperature increased. Vogel in 1873 made the discovery that by treating photographic materials with certain dyes one could make them respond to wavelengths of light to which they were not naturally sensitive. However, through the greater part of the 19th century there was no known way of photographing in the infrared band. By 1900 astronomers could record the spectrum of the sun to 900 nm* by using certain dyes which functioned in the near infrared. However, these were not very useful for general photography. A dye called Dicyanine was found before 1919 and used for spectrography, but the first really practical infrared dye was Kryptocyanine, discovered in 1919 at the Bureau of Chemistry in Washington. Until 1935 the best sensitizer for the extreme infrared was the dye Neocyanine made by Kodak in 1925.

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*By a recent international agreement among scientists, the term "nanometer" (abbreviated "nm") replaces the equivalent term "millimicron" when speaking of a unit of distance which is 10^{-9} meters and the term "micrometer" (abbreviated "μm") replaces the term micron when speaking of a unit of distance which is 10^{-6} meters.

With the addition of a great many very good sensitizers for the infrared during the years 1931-1935, all the dyes previously known, with the exception of Kryptocyanine, were found to be obsolete. Photography was possible out to 1.35 micrometers and that remains as the practical limit today. Infrared photography became as easy to obtain as ordinary photography and a new and continuing era of infrared photography set in. The U.S. Air Force and the National Geographic Society-U.S. Army Air Force Stratosphere Flights were the two main boosters in the development of infrared aerial films.

In 1933 Captain A. W. Stevens of the USAF on one of his stratosphere flights photographed Mt. Shasta with infrared film at a distance of 331 miles from an altitude of 23,000 feet. Infrared photography was obtained on the first, ill-fated stratosphere flight in 1934. The photography was reported as being somewhat underexposed, however. During the N.G.S.-USAF stratosphere balloon flight that was made on November 11, 1935 over South Dakota, an altitude of 72,395 feet was attained. Infrared photographs obtained on that flight were very successful.

Spectacular high-altitude and long-distance tests were made shortly thereafter by the Air Force, while Bradford Washburn obtained some excellent photographs of Alaska in 1938. By March, 1937, the first infrared aerial film was made commercially available to the general public. Kodak put out the improved Infrared Aero Film, type 21, as the result of tests conducted by Colonel Goddard in October, 1940.

Hypersensitive infrared aero film followed in 1943. Later, the present types of infrared film of improved quality, higher speed, and better keeping properties were made available.

The fact that black-and-white infrared films are also sensistive to a significant degree throughout the visible spectrum is exploited in some modern day systems which, as explained in a later section, seek to register and color enhance multiband black-and-white photographs with the aid of an optical combiner. For example, a single 9"x9" frame of such film can be treated as though it were divided into quarters. Then, with a four-lens camera that will accomodate the full width of the roll of film, and using four filters, a separate band of photography is recorded in each of the four quarters by the simultaneous operation of the camera's four lens shutters. The four bands most commonly recorded are blue, green, red, and near-infrared, and the corresponding four Wratten filters used are 47B, 58, 25, and 89B. The optical combiner used with such a system is carefully aligned so that all four of the images that have been recorded on a single 9"x9" piece of film are in common register when projected, through appropriately colored filters, onto a viewing screen. Once this careful registration has been achieved, no re-registration is required to view successive frames of multiband imagery because, on all such frames, the four quarters are positioned identically on the 9"x9" frame. This same capability cannot be exploited on even the best of panchromatic films since they all are so constructed as to be insensitive to near-infrared wavelengths of energy.

The first suggestion to combine infrared and panchromatic photographic emulsions with color processing apparently was made in early 1941. From the Kodak Research Laboratories in England, Spencer and Marriage reported on this possibility for detection of military camouflage. After enlarging and experimenting on their general proposals in the Kodak Research Laboratories in Rochester, New York, they developed three different structures for a multilayer film. These included an infrared layer along with false color processing. In the names of Jelly and Wilder a patent was filed on the basic structure on October 24, 1942 and the patent was issued on July 9, 1946.

The origin of what the Russians call spectrazonal film can be found in the description of a narrow band material having layers responding to peak sensitivities at wavelengths of about 680 nm and 740 nm, respectively. Between these two bands are the wavelengths within which chlorophyll, unlike most other materials, changes dramatically from an energy absorber to an energy transmitter. Use of these wavelengths, consistent with the basic principles of multiband photography, should readily permit the photo interpreter to differentiate between green vegetation and any green paint used by the military camoufleur. Originally color development of spectrazonal film was by means of direct coupler development or by "toning." It was determined, however, that by using the camouflage detection type of false color film and exposing it through a red filter and, then, before processing, further exposing it to flashing green light (to eliminate the yellow layer) one could obtain the same results.

Other proposals were made by Capstaff in 1941 to have a three-layer, false-color film with at least two of the layers sensitive to different regions of the infrared, and the third layer sensitive to visible light or to a third band in the infrared. There appears to be no advantage to such a material over the available structures, however. Kodak Ektachrome Infrared Aero Film, Type 8443, first made available to the military as Aero Kodacolor Reversal Film, Camouflage Detection, proved to be a greatly improved infrared false-color material. Its properties are described in a later section.

During the past two decades aerial infrared color photography, and more especially false color infrared photography, has been commanding increasingly greater interest by both military and civil agencies. It is likely that the color version will continue to be preferred over the black-and-white in many applications. Too often, however, the extra expense is unwarrented because the color adds little more than aesthetic appeal. This, I am sure, is what prompted one of my photo interpretation colleagues of World War II days to exclaim as we sat side-by-side in the audience at a recent remote sensing symposium in which each speaker showed his color infrared slides: "Bob, sometimes I wonder if the whole world isn't turning red!"

Kodak Ektachrome Infrared Aero Film, Type 8443, with its increased speed and quality, might well be used for two-color spectrazonal photography. It could perhaps also be a useful single film for multiband spectrazonal photography with proper filter use.

N. The Projection of Color

Again placing recent developments into historical perspective, let us emphasize that, shortly after a capability for obtaining black-and-white photography had been developed, serious consideration was given to means by which, through projection, photography in full color might also be obtained.

For example, as early as 1855 in a paper on color vision, James Clerk Maxwell gave a hypothetical example to clarify a discussion of Young's theory of vision. This was, in fact, the invention of color photography. Speaking of Young's theory, Maxwell wrote:

> "This theory of color may be illustrated by a supposed case taken from the art of photography. Let it be required to ascertain the colours of a landscape by means of impressions taken on a preparation equally sensitive to rays of every colour. Let a plate of red glass be placed before the camera, and an impression taken. The positive of this will be transparent wherever the red light has been abundant in the landscape, and opaque where it has been wanting. Let it now be placed in a magic lantern, along with the red glass, and a red picture will be thrown on the screen. Let this operation be repeated with a green and violet glass, and by means of three magic lanterns, let the three images be superimposed on the screen. The colour of any point on the screen will then depend on that of the corresponding point of the landscape; and by properly adjusting the intensities of light, etc., a complete copy of the landscape, as far as visible color is concerned, will be thrown on the screen."

A more lucid description could scarcely be written even today regarding the use of an "optical color combiner" to produce a composite color image from black-and-white photos that have been taken with various film-filter combinations.

Maxwell later demonstrated the above operation on May 17, 1861.

Toward the end of the 19th Century, Louis Ducos du Hauron developed three-color separation to a fine art and made beautiful color prints using red, yellow, and blue pigments. In 1895 he made a most interesting observation:

> "During my last researches I have discovered a marvelous law by virtue of which an image, composed of two monochromes is capable of producing on the visual organs, under certain conditions, a colored sensation as complete as the trichromatic images which I have already obtained. The novelty consists in eliminating the yellow monochrome, but taking and superimposing the red and blue monochromes as usual. . . The phenomenon that I have suggested requires one condition and that is that the double image should be examined, not by white light, and plenty of it like bright sunlight, but rather by weak daylight and just enough to see the subject, or better still by the yellow light of candles or lamps. Viewing the result by daylight is possible, with very great reduction of the light, if the image is produced on a yellow or gray support. It should be noted that under these conditions the yellow sensation cannot be attributed to the yellow illumination nor the yellowish surface on which the print is made. In fact the white parts of the scene are rendered as white while the yellows are rendered as yellow. Observers actually believe that they see the three colors where they ought to be although they know they are actually absent."

Another milepost dealing with color photography is to be found in Land's work with two-color projection as reported to the National Academy of Sciences in 1959. In one projector Land included a "short record" consisting of a panchromatic exposure transparency taken with a Wratten 58 (green) filter and in the other projector he included a similar exposure taken with a Wratten 24 (red) filter. This is referred to as the "long record." Land devised a coordinate system based on short vs. long stimuli and plotted the resulting colors showing that, with a monochromatic light source, many colors are possible and that different combinations of wavelengths will yield the same color. He also discussed negative-positive projection systems as well as double contrast. In the latter case, one projector has two of the same transparencies in it, while the other projector has but a single transparency of the opposing record; he notes that the result is not as the classical theory of color predicts; instead the effect is the same as that produced when projecting single transparencies from both projectors.

D. Development of Color Film

In 1924 Mannes and Godowsky patented their first work on a multiple layer color film which eventually led to the development of Kodachrome. There has been emphasis on three-color systems ever since the three-layer color film came on the market in 1935. Almost immediately there developed an interest in the applications of color to aerial photography. In 1937, Colonel George Goddard made preliminary tests and was soon followed by Bradford Washburn and Walter Clark as they made aerial Kodachrome pictures of southeast Alaska in 1938.

The question soon arose of whether to make color film which could be developed to a negative or to a positive. It was decided that "reversal positive film" was the type that should be made available to the military during the war. This was done and the film was designated as Kodacolor Aero Reversal Film, which was the forerunner of Ektachrome.

As previously indicated, in World War II infrared false color film was made available to the military for testing as "Aero Kodacolor Reversal Film, Camouflage Detection." A currently used infrared color film known as Kodak Ektachrome Infrared Aero Film, Type 8443, is basically a modification of the Type B structure recommended by the Air Force in 1942.

Several other developments that might well be included in this "historical" section are discussed more appropriately in the sections which follow, as we seek to set the stage in this introductory paper for subsequent phases of our week-long Conference of Remote Sensing Educators.

II. THE DEVELOPMENT OF PHOTO INTERPRETATION AND REMOTE SENSING DURING THE PAST QUARTER CENTURY

It seems appropriate to include in this paper a separate major section dealing with developments of the past quarter century in photography and related aspects of remote sensing. Hopefully, as a result of our so doing, we will better know (in Abraham Lincoln's words) "where we are," the better to develop, in a subsequent section that looks to the future, an intelligent forecast of "whither we are trending." As in the previous sections, this one will itemize, under discrete headings, the most important of these specific developments.

A. The Post-War Surge of Interest in Photo Interpretation

Anyone who has had the exhilarating experience of attending the annual national meeting of his professional society is likely to have gained the impression that his profession is growing by leaps and bounds and is commanding the interest of most of the thinking world. This is exactly the feeling that many remote sensing scientists have received, year after year, at annual meetings of the American Society of Photogrammetry, as they have talked with their fellow workers about the future of photography, photo interpretation and other aspects of remote sensing. With the benefit of 20/20 hindsight they now can perceive that, until quite recently, most of what they were experiencing was little more than a warm glow at being in the presence of some hardworking professional associates who were committed to earning a living in the same fields of endeavor as that in which they, themselves, were engaged. Much can be said for having such a rejuvenating experience once a year. However, we must differentiate the enthusiasm of professional colleagues from that of the rest of the scientific community, without whose support most of the concepts discussed in this paper might never have progressed much beyond the "warm glow" stage. What evidence is there then that modern remote sensing technology, in general, and photo interpretation, in particular, has recently won this acceptance by other scientists?

Certainly some evidence for this claim resides in the fact that, during the past quarter century, scientific and professional societies representing a tremendous variety of disciplines have displayed great interest for the first time in various aspects of remote sensing. The technical sessions held at their annual meetings have reflected this interest by highlighting papers, and even whole symposia, on one aspect or another of remote sensing. Usually the emphasis, especially in the last few years, has been on recent developments in the acquisition and analysis of multiband imagery and/or digital data indicative of scene brightness. Among the professional societies in the United States that frequently have held such technical sessions and continue to do so are the American Association for the Advancement of Science, the American Astronautical Society, the American Institute of Biological Sciences, the National Geographic Society, the Optical Society of America, the Society of American Foresters, the Range Management Society of America, the Ecological Society of America and at least three groups within the National Research Council (Division of Biology and Agriculture, Earth Sciences Division, and Agricultural Research Institute).

As a corollary, it has been during this same period that articles dealing with remote sensing have for the first time been featured in the professional journals of most of these societies and also in some of the more popular magazines, such as Time, Newsweek, Scientific American, Popular Mechanics, and National Geographic Magazine. As further evidence, the highly prestigious professional journal of the American Society of Photogrammetry, which for years had been known simply as "Photogrammetric Engineering" began featuring so many articles on photo interpretation and other aspects of remote sensing that its name was changed, during this same period, to "Photogrammetric Engineering and Remote Sensing."

What has just been said regarding the increased interest in remote sensing by scientists in the United States appears to be true in several other countries as well, especially in Western Europe and Australia.

Evidence leading to this conclusion is provided by the steadily increasing number of international symposia on various aspects of photo interpretation and remote sensing that are being held at several places throughout the world. To take an example which proved to be especially successful, it was in 1966 that scientists from a great variety of disciplines combined their efforts and produced a World Congress in Cologne, Germany, on uses of photography and other forms of remote sensing in industry and technology. Those who presented papers there on some of the most modern and highly sophisticated forms of photo interpretation and remote sensing technology were gratified to find out their presentations were regarded, for the most part, as the highlights of the meeting. As another example, the United Nations organization has in recent years sponsored at least three "Regional Cartographic Conferences," and a like number of sessions at the UN's FAO Headquarters in Rome, all of which have emphasized potential applications of photo interpretation, primarily in relation to the inventory and management of natural resources and primarily for the improvement of lesser developed countries.

B. The Impact of World War II's Photo Interpretation Trainees

Shortly after the end of World War II a very significant development occurred in relation to the increased use of remote sensing throughout the globe. For example, in the United States at that time there were at least 1,000 photo interpretation officers (more than 600 of them from the Navy, alone) released from active duty to return to their civil pursuits. These were individuals who had been recruited during the war, commissioned as reserve officers and then trained and given a great deal of operational experience in various aspects of aerial photographic intelligence. Upon completion of the war the vast majority of them returned to civil life to work in the professions from which they had been recruited. Most of these professions dealt, in one way or another, with the earth's natural resources--professions such as geology, forestry, range management, soil science, hydrology, and the agricultural and engineering sciences. Almost all of these individuals had the following combination of attributes: (a) they possessed a B.S. degree in one of the above listed disciplines; (b) they possessed good qualities of leadership, much of it having been developed during their service as military officers; (c) by virtue of their military training and experience in studying aerial photos to assess "trafficability conditions" (i.e., conditions governing the movement of personnel and various kinds of mechanized equipment), they were well aware of both the uses and the limitations of aerial photos in assessing certain kinds of information that would be of interest also to the manager of natural resources (e.g., information with respect to terrain analysis, vegetation identification, and soil mapping); (d) they were young, vigorous and eager to build on their military-acquired experience, if possible, as they returned to pick up the threads of their pre-war careers; and (e) they were well qualified, and usually well motivated, to teach others how to interpret aerial photographs.

The impact of these individuals on the development of remote sensing in the United States during the post-war era can scarcely be overemphasized. Reportedly other nations benefited in a similar manner as their military-trained reservists returned to civil life.

As listed below there were at least four other important training-related developments that occurred in a great many countries during the post-World War II era with respect to remote sensing.*

(a) The rapid increase during the post-war era in university-level course offerings dealing with one aspect or another of photo interpretation and photogrammetry;

(b) Associated with the above item, the rapid increase in the number and quality of textbooks dealing with aerial photographic interpretation and photogrammetry;**

(c) The rapid increase in the number, quality and types of equipment for use in photo interpretation and photogrammetric activities; and

(d) The growing stature of photo interpretation in various professional societies.

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*By this point in my paper it will be apparent that the term "remote sensing" is sometimes used instead of "photo interpretation" for the following reason: photo interpretation pertains specifically to the study of photographic images for the purpose of identifying objects and judging their significance; the broader term, remote sensing, has come to mean all of this, plus data acquisition as well.

**This topic is to be covered quite fully in a paper that is to be presented by Rudd et al, later in this conference (Ref. 11).

C. Founding of an International Commission on Photo Interpretation

An international development of particular significance in the growth of remote sensing was the formation in 1952 of a special Commission on Photo Interpretation (Commission VII) within the International Society of Photogrammetry. In my capacity as the president of that commission for the first eight years, or so, of its existence, I can clearly recall that during that period the assertion frequently was made by photogrammetrists that photo interpretation was not of sufficient stature to merit its own commission. Such an assertion is rarely, if ever, heard now, thanks largely to the steadily increasing stature acquired by photo interpretation during the post-World-War II period.

As pointed out (Ref. 12) in a recent review of Commission VII's activities, part of the steadily increasing interest in remote sensing that has occurred during the past quarter century has resulted from the great increase that has occurred during that time in both the total amount and the availability of photography and other types of remote sensing data. Many of the "Johnny-Come-Latelies" to the field of remote sensing find it hard to believe that, in the early 1950's photo interpreters in the United States and, indeed, throughout the globe, were continuing to work (as in previous decades) almost entirely with a single type of imagery. It was almost invariably black-and-white vertical aerial photography, that had been taken at some time during the preceding 10-year period, probably during cloud-free midsummer high sun angle conditions, using panchromatic film and a "minus blue" filter, and employing a camera having approximately an 8-1/4" focal length and a 9"x9" negative size, operated from an altitude of 13,750 feet above the terrain to give a photographic scale of 1/20,000, or thereabouts. While the great potential benefits of acquiring and interpreting multiband, multidate, and multistage photography were recognized, it was totally unrealistic in most instances to consider that such kinds of photography could all be made routinely available to the photo interpreter at any foreseeable future date.

At this point let us examine quite specifically the role of Commission VII in relation to the photo interpretation progress that is about to be discussed.

Until Commission VII (Photo Interpretation) of the International Society for Photogrammetry was founded in 1952 there was no organization which might logically serve as the international "clearing house" on photo interpretation matters. Prior to that time, therefore, there was needless duplication of effort both in the conduct of research and in the reporting of results and activities relative to the field of photo interpretation. In many instances, the problem was one of omission rather than duplication.

Each of the other commissions of the International Society for Photogrammetry (ISP), having been formed many years earlier, had solved such problems primarily through (1) the appointment of reporters from each of the countries most active in that aspect of photogrammetry with which the commission was concerned; (2) the publication of pertinent articles, papers, and newsworthy information in Photogrammetria, the official publication of the ISP; (3) the organizing and presenting of international symposia once every four years as part of the quadrennial meeting of the ISP; and (4) the publication of a very complete and prestigious record of the proceedings of those quadrennial meetings of their commission. For each such commission it was common practice that the Commission's president and vice-president for any given four-year period be appointed from two of the countries that currently were most active in work of the type dealt with by the Commission.

All of those highly desirable attributes have been emulated by Commission VII from the very time of its formation. It is in consequence that this part of my paper, dealing primarily with progress in photo interpretation in the past quarter century, indirectly constitutes a tribute to the activities of Commission VII since its founding in 1952.

D. Efforts Aimed at the Systematic Training of Photo Interpreters in the Post-War Era.

It was roughly a quarter century ago that one of the first attempts was made to list the most significant components that govern the quality (and hence the interpretability) of photographic images and to categorize the various measures that might be taken to rectify image deficiencies. As set forth at the time (Ref. 13) there reportedly were three such components, viz., the tone or color contrast between a photographic image and its background; the sharpness of the image as measured by the abruptness with which this tone or color change occurred on the photograph at the "edge" of the image in question; and (applicable only in the event that the feature in question had differences in elevation with respect to its background), the amount of stereo-parallax exhibited by the image. Stereo parallax is defined as the shift in the apparent position of the image with respect to its background caused by a shift in the point of observation (as when the camera station shifted from the point from which the left member of a stereo pair of photos was taken to the point from which the right member of that pair was taken).

It was recognized that the factors which govern any one of these image quality characteristics are, for the most part, different than those which govern either of the other two. Thus, it was pointed out that there were four primary factors governing the tone or color contrast (spectral reflectivity of the feature and its background; spectral sensitivity of the film; spectral transmissivity of the filter; and spectral scattering by atmospheric haze particles). Similarly there reportedly were four primary but quite different factors governing image sharpness (aberrations of the lens system; focus of the lens system; image motions at the instant of exposure; and characteristics of the photographic materials). Finally, there were considered to be three primary factors governing stereoscopic parallax (altitude of photography; length of the stereo base as governed by the distance between overlapping exposures; and difference in elevation between the feature and its surroundings).

Even to this day, the rather simplistic treatment of image quality that has just been given would seem to have merit in each of two respects:

(a) It is highly meaningful to speak of three separate measures of the visual acuity of the image analyst which are almost identical with these three image quality characteristics. Specifically, it is highly relevant for three corresponding questions to be asked: (1) To what extent can any given image analyst (or applicant for work involving image analysis) perceive differences in tone or color contrast between an image and its background (e.g., does he have some kind of color blindness?)? (2) To what extent can he resolve fine detail and thus exploit the sharpness of an image? (3) To what extent can he perceive stereoscopic parallax, if at all? Unfortunately, some image analysts have only one good eye.

(b) It follows from the above that a competent image analyst, on examining a given type of imagery, can determine to what extent that imagery is of suitable quality in terms of each of these three attributes. If, on making such a determination, he finds deficiencies in one or more of these attributes and wishes to make improvements in that attribute when acquiring additional imagery in the future, he needs only to turn to the list of factors described above that govern the quality of that attribute. In so doing he can promptly learn what approach needs to be used in rectifying the deficiency, whatever it may be, when more photography is being taken.

Two measures of image quality that were being developed at about the same time as the above have become known, respectively, as "acutance" and the "modulation transfer function." Both of them probably are more precisely measurable and consequently more appealing to the physicist and mathematician than the "tone-sharpness-parallax" concept that has just been described. But experience has shown that both of them are much more difficult for the average image analyst to comprehend, and to identify with. Furthermore, neither acutance nor the modulation transfer function gives due consideration to stereoscopic parallax. Instead, each concerns itself primarily with the "sinusoidal response curve" that is obtained when a plot is made of the change in tone or brightness per unit of distance along the edge or perimeter of a feature, as imaged on photography. Acutance deals with only one such edge (e.g., the classic photograph of a "knife edge") while the modulation transfer function deals with a whole sequence of such edges, repetitively spaced, but at progressively closer distances, as in a resolution target.

By about 1960, a systematic approach to the factors governing the amount of information derivable from image analysis tended to deal in one way or another with four components, only the first of which has been alluded to in the preceding paragraphs. These components, at least as set forth in one representative treatment were described in the following statement (Ref. 14): "If aerial photo interpretation in any of its applied forms is to be employed successfully, four conditions must be satisfied: (a) the aerial photography must provide images of suitable quality for extracting the type of information that is to be obtained through photo interpretation; (b) the men performing the photo interpretation work must have been properly selected and trained; (c) the equipment used in viewing, measuring, and interpreting the photographic images must be of suitable quality; and (d) the methods and techniques used by the photo interpreter must permit him to extract the information both efficiently and accurately."

In discussing the second of the above-listed considerations, this reference made the following rather optimistic statement which perhaps needs to be re-evaluated in light of developments since it was written, nearly 20 years ago:

> "Until recently there was a tendency to assume that one person was as well suited to photo interpretation work as another. Consequently, the selection process revolved primarily around considerations as to the relative availability of two or more people to handle an additional task, in this instance aerial photographic interpretation. However, we are gradually coming to realize that the differences between a good photo interpreter and a poor one can be largely explained on the basis of (1) differences in visual acuity, (2) differences in mental acuity, and (3) differences in general attitude toward the photo interpretation task."

That article then traced seeming progress in each these three areas, cited a very successful 11-phase aptitude test for photograph users and announced the recent finding of "highly significant correlations between the candidate's photo interpretation abilities and his abilities in general mathematics, mechanical principles, and arithmetic reasoning," and speculated on the probable importance of "capacity for learning, adaptability, and powers of judgement." It also included a sample test that might be applied for determining a candidate's attitude toward the photo interpretation task, and discussed recent improvements in photo interpretation training methods, materials, and equipment. In retrospect, we can see that progress has been much slower in the 20 years since, particularly in implementing the various findings and concepts referred to above, than had been anticipated. On the other hand, a rather cautious understatement was made in that reference with respect to the future use of computers. The statement simply cited their increased use by photo interpreters "to make multiple correlation analyses, derive multiple regression equations, and determine the statistical reliability of various sizes of samples and methods of sampling."

Finally, that article of nearly 20 years ago, in discussing recent improvements in the methods and techniques of photo interpretation cited (a) methods for orienting a stereo model beneath the stereoscope; (b) methods for handling a large stack of photos in an orderly manner during the photo interpretation process; and (c) methods for avoiding duplication or omission in the interpretation of areas common to two or more overlapping photographs. In retrospect we perceive that no significant break-throughs in any of these mundane methods, common though they are to virtually all kinds of photo interpretation, have been made in the interim.

In looking to the future that article was quite correct in predicting that "for the first time, extremely small scale photography taken with a photo reconnaissance satellite from an altitude of nearly 200 miles will be available for civil as well as military photo interpretation work." Modern day remote sensing scientists might disagree with the sentence which followed in which it was asserted that "this photography will permit us to do little more than discover and evaluate, in crudest terms, the natural resources in vast and remote areas, but will be of tremendous value in helping to plan for the economic growth of underdeveloped countries."

E. Improvements During the Past Quarter Century in Sensor Platforms and Sensor Systems.

All of the attendees at this conference must surely realize that modern day space photography permits us to do much more (not little more, as was predicted in the concluding sentence of the preceding paragraph) than merely to "discover and evaluate, in crudest terms, the natural resources in vast and remote areas." Part of the explanation is found in our having underestimated the potential advantage that would be given to a photo interpreter by the overall "synoptic view" as recorded from an altitude of one hundred miles or more and covering a ground area per frame of photography that was at least a thousandfold greater than that to which he was accustomed. But another part of the explanation results from our failure, prior to the dawning of the space age, to perceive the remarkable improvements that would be made in cameras and other sensor systems. For instance, the aerial photography of a quarter century ago rarely permitted more than 25 line pairs per millimeter to be discerned. Since then, improvements in both the emulsions of photographic films and the optics of sensor systems have been sufficient to make quite commonplace a fourfold improvement in such resolution. Furthermore, serious discussions regarding the potential for obtaining fortyfold improvements frequently are heard.

There also have been some startling improvements in recent years in various other kinds of sensor systems, including panoramic cameras, continuous strip cameras, optical mechanical scanners, and side-looking airborne radar systems. Each of these systems, when used individually aboard a spacecraft, is able to provide certain kinds of information that cannot be obtained from any of the others. More importantly, when the remote sensing data that has been acquired by several of these sensor systems is placed in the hands of a competent image analyst, the "convergence of evidence" principle can be exploited in respects that heretofore were not feasible, thereby adding greatly to the amount and accuracy of information derivable from space-acquired remote sensing data.

F. Improvements During the Past Quarter Century in Capabilities for the Analysis of Remote Sensing Data.

The techniques and equipment used by humans in the analysis of remote sensing data were, for the first time, comprehensively described and illustrated in the Manual of Photographic Interpretation as mentioned previously (Ref. 2). Since then, great advances have been made in developing capabilities for the analysis of remote sensing by machines. As a result, there is today a valuable and extensive field of photo interpretation (or more broadly stated, of "computer assisted analysis of remotely sensed data") that was virtually unknown a quarter century ago. For example, almost no mention of this capability appears in the previously mentioned "Manual of Photo Interpretation" (Ref.2), whereas it constitutes a very major part of the material contained in a companion volume published 15 years later and entitled "Manual of Remote Sensing" (Ref. 4).

Because of this modern day dual approach to the analysis of remote sensing data some very important questions currently are being addressed

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*This fact is well illustrated if we consider, for example, the unique combination of advantages inherent in Landsat-acquired data, as set forth in Table 1.

Table 1 Valuable characteristics of Landsat data in relation to the inventory and monitoring of earth resources.

(No other vehicle-sensor system provides this important combination of characteristics).

1. Multispectral Capability
   A. Senses for the optimum wavelength bands for use in the inventory and monitoring of most types of earth resources (timber, forage, agricultural crops, minerals, water, atmospheric and oceanographic resources).
   B. Provides high spectral fidelity within each of these bands.

2. Multi-Temporal Capability (Provides Multiple "Looks" for Monitoring Seasonal Changes in Vegetation, Rate and Direction of Plant Succession and the Accumulation or Receding of Snow or Flood Waters).

3. Constant Repetitive Observation Point (Facilitates Change Detection by Matching of Multi-Temporal Images).

4. Sun-Synchronous (Nearly Constant Sun Angle) Ensures Nearly Uniform Lighting and Uniform Image Tone or Color Characteristics for Use in Feature Identification.

5. Narrow Angular Field of Sensors (570 Mile Altitude and Only 115 Mile Swath Width Avoids Tone or Color "Fall Off" at Edges of Swath and Thus Increases Still Further the Uniformity of Image Tone or Color Characteristics).

6. Provides Computer-Compatible Products Directly (Facilitates Automatic Data Processing).

7. Potential Minimum Delay in Data Availability to User (Permits "Real-Time" Analysis and Facilitates Making Globally Uniform Resource Inventories, when Appropriate, or Analyzing Troubled Areas such as Sahel, in Africa).

8. Systematic Coverage of Entire Earth Except for Near-Polar Regions.

9. Capability for Receiving Data from Ground-Based Data Platforms (Facilitates Use of "Ground Truth" Data in the Inventory and Monitoring of Earth Resources).

10. Spatial Resolution is Optimum for "First Stage" Look and is Politically Palatable, Both Domestically and Internationally.

11. Data Routinely Placed in Public Domain for Benefit of All Mankind.

relative to ways in which the human and the machine should interface in order to bring about the most complete, accurate, and expeditious analysis of remote sensing data through a suitable combination of human and automated data analysis. More information with respect to this important topic will be found in a later section of this paper that deals with a look to the future.

G. Controversies of the Past 25 Years Relative to the Usefulness of Photo Interpretation Keys.

Evidence of the interest commanded by photo interpretation keys a quarter century ago is to be found merely from a survey of the literature for that period. For example, this matter was of such interest that in 1952, in the Report of the President of Commission VII (Photographic Interpretation) to the International Society of Photogrammetry (Ref. 15), almost half of the entire report was devoted to discussing and illustrating such keys and to a parallel discussion of terminology problems and solutions associated with their use. Yet, despite that seemingly disproportionate allocation of space to one topic, photo interpretation keys were again the primary topic at the 1955 annual meeting of the American Society of Photogrammetry in the course of which a panel presentation consisting of no less than nine papers was devoted to this subject. Although it is probable that the hey-day for photo interpretation keys has passed, their usefulness both as training aids and reference manuals should not be dismissed, even up to the present time.

One of the most definitive tests ever performed relative to the effectiveness of photo interpretation keys as training aids was conducted in the United States using 60 high school students as the test subjects and a dichotomous key contained in the book "Pacific Landforms and Vegetation" as the test material. Specifically, the key tested dealt with wildland vegetation types such as Nipa Palm, Casuarina, Mangrove, and Moss Forest--types which no one in the test group had ever seen or perhaps even heard about. Within a six-hour day of instruction the students, starting from "ground zero",were first taught the principles of aerial photography and stereoscopy and given practice in the three-dimensional viewing of overlapping vertical aerial photographs through a stereoscope. They were then taught the principles and use of the dichotomous key that was to be tested, a key dealing with the wildland vegetation types of the Tropical Pacific Area. Finally, during the last hour each student was given a set of operational photos of a representative portion of the Tropical Pacific Area within which were to be found some of the most complex vegetation associations that might be encountered anywhere in the world. The students were asked (1) with the aid of the key to identify the type of vegetation, area-by-area, and (2) with the aid of supplementary statements which accompanied the key and which dealt with the "trafficability conditions" known to be associated with each vegetation type (i.e., statements describing the ease or difficulty with which either personnel or various kinds of mechanized equipment could traverse the area) to delineate on the photographs the best route of travel from point-to-point. Fully one-third of the students identified the many vegetation types with nearly 100 percent accuracy and selected point-to-point routes of travel that were known to be among the most favorable, based on "ground truth."

Despite encouraging findings such as these, photo interpretation keys seem to be less used today than 25 years ago, and certainly to command less interest as topics for discussion at a conference such as this one.

III. THE ROLE OF EDUCATION TO DATE IN THE DEVELOPMENT OF REMOTE SENSING TECHNOLOGY

The rather extensive historical review that has just been given should enable us to answer, in the present section, several specific questions that were addressed to us by the conveners of this conference. One of these questions relates to the role that training has played to date in the development and acceptance of remote sensing technology. Another question asks whether it seems, in the light of this historical review, that the period of time that has been required for development to date of this technology has been inordinately long. Still another asks whether better training might have accelerated the rate at which remote sensing technology has been developed and accepted to date. These and related questions prompt us to devote most of the present section to a brief summary of the training activities that have accompanied remote sensing development and acceptance up to the present time.

The adequacy with which we are able to respond to these questions in the present section obviously will govern in large measure our success in writing a concluding section of this paper which, as previously indicated, is to deal with the probable future of remote sensing technology and training.

Usually, when an important new science is being developed, and especially one that offers great and immediate practical benefit to mankind, there is a parallel development in textbook writing and in the offering of formal instruction. As a result, the training never lags far behind the basic scientific developments themselves, and soon it becomes acknowledged that an important new discipline has emerged. Furthermore the steady stream of enthusiastic and knowledgeable trainees produced by such a process does much to hasten the rate of technology acceptance.

Such does not appear to have been the pattern in the early days during which the development of photography was occurring. In fact it seems apparent that during the century following the discovery of photography, training was not a significant activity in relation to the development and acceptance of remote sensing technology. This statement is based not only on the present writer's own appraisal but on the similar conclusions, whether stated or implied, in the 10 historical reviews that are cited earlier in this paper.

Instead, the following somewhat restrictive activities (i.e., activities designed to discourage general acceptance of remote sensing technology) appear to have occurred during that period.

1. The patenting of photogrammetric principles (such as the radial line plot process) and even the simplest but highly practical equipment designed to exploit those principles (such as the slotted template cutter), and

2. The withholding of information on some of the most spectacular successes in the field of military photo interpretation on grounds of military security. Thus, it was only belatedly made known, for example, that an obscure but highly authoritative military report written at the end of World War I documented the following fact: In the very sizable front line sector that was occupied by American forces during World War I more than 90 percent of the enemy's fortifications and related weaponry were correctly located and identified by means of aerial photographic interpretation. Yet at the start of World War II there was not a single officer in the entire U.S. Armed Forces who had been trained to interpret aerial photos for military purposes. Consequently, within the United States, virtually the entire field of aerial

photographic intelligence had to be "rediscovered" early in World War II when a Navy lieutenant, Robert S. Quackenbush, and two associates, visited England and observed the techniques which were being developed and/or rediscovered by British military authorities under the desperate urgency of the Battle for Britain and the threat of German invasion. To this day some authorities claim that the primary factor that thwarted the long-threatened invasion of Britain by German troops was the 11th hour discovery by British photo interpreters, and the consequent destruction by air attack, of invasion boats and barges that were being massed in canals near the coast of the mainland of Europe, just across the channel from England.

The reported withholding of some of the successes achieved by geologists in using aerial photo interpretation for the discovery of mineral and petroleum deposits constitutes another example of action designed to discourage the rapid and general acceptance of photo interpretation. In this instance the withholding was in the interest of maintaining "trade secrets," sometimes categorized by private enterprise as "company confidential." It is not known, however, how commonly this action was taken.

Without question, the most important training activity leading to the rapid development of remote sensing in the past three decades was that given to civilians by the U.S. Armed Forces in general and by the U.S. Navy in particular, during World War II. For two reasons I propose to develop this thesis quite fully: (1) Because of its great impact on modern day remote sensing it is at the very heart of the topic that I was asked to deal with in this paper, viz., the role of education to date in the development of modern remote sensing technology; and (2) There is no topic of historical relevance to this Conference of Remote Sensing Educators on which I personally could speak more authoritatively since (a) I was in charge of the Navy's training programs in photo interpretation and photogrammetry during most of this time, and (b) during the rest of World War II, I was either working side-by-side with or else commanding large numbers of these photo interpretation trainees from all branches of the U.S. Armed Forces.

During World War II the Navy, unlike the other branches of the U.S. Armed Forces, had the following policy for selecting trainees: (1) Only officers will be trained; (2) Because all officers of the Regular Navy are greatly needed to man ships, aircraft, and the supporting shore establishments, all of the officers trained to interpret aerial photos will be Reservists; and (3) These Reservists, by and large, should be selected from professions which deal with the plan view, in general, and with maps in particular, because such individuals can more readily comprehend what they see on vertical aerial photographs.

A more stark demonstration of the wisdom of this Navy policy could scarcely be envisaged than the one which centered around the planning and execution of the Okinawa campaign of World War II. The photo intelligence component for that operation consisted of more than 100 officers and men from all branches of the Armed Forces--all of whom had been "trained" to do photo interpretation work. Throughout the entire one year period required for the planning and execution of the Okinawa operation I was in charge of these individuals in my capacity as "Chief of Photo Intelligence" and was able to make rather close observation of the individual performances of a great many of them. Belatedly I learned why the family names of so many of the photo interpreters on the roster of the <ins>Army</ins> contingent that was assigned to me were difficult for many of us to spell and pronounce. The majority of these individuals came from American families of very recent mid-European extraction, families in which mid-European languages were even spoken in the homes. It was for this reason that these individuals had, indeed, been selected by the Army to perform intelligence work--not that related to the interpretation of photographs, but to the interrogation of prisoners of war. For the latter type of assignment it obviously was logical to select individuals who could speak the native language of those captured. How, then, did they happen to end up, not as language specialists in the European Theater of Operations, but as photo interpreters in the vastly different Pacific Theater of Operations? By their own testimony I learned the answer: These particular individuals (i.e., many, but not all of the Army photo interpreters sent to Okinawa) were merely the ones who had failed the course to which the Army originally had sent them, viz., the course in which they were to learn how to interrogate prisoners. What then should the Army do with such flunkees? Why not keep them in the "intelligence specialty" of the Army, but make photo interpreters out of them instead--whether they could see stereo or not--indeed whether they could even see or not--let alone considering whether they had any background of training and experience in work related to photo interpretation--or any aptitude for and/or interest in such work. And so this was done!

Partly because many of these men lacked the aptitude and interest, they availed themselves of opportunities to do something "more important than" photo interpretation. And what could that be, in the height of battle, with men on the front lines desperately in need of photo intellignece support? Here again, the answer is not a pleasant one, but one to which I can attest -- hopefully with relevance to my assigned topic here today -- and certainly with great authority. The answer relates directly to the policy then in effect in the Army, vastly different than that in the Navy, that photo intelligence should be done by six-man teams, consisting of two officers and four enlisted men, each team being equipped with a vehicle, its own cameras and photo lab facilities, and perhaps as an afterthought a pocket stereoscope or two. With these opportunities for distractions the result would have been quite predictable. The senior of the two officers emerged as the "Commanding Officer" and the other as the "Executive Officer" and were able to busy themselves, essentially on a full time basis, with the task of administering their vast command of four enlisted men. This would at least seem to leave the four enlisted men unencumbered to do the photo interpretation work, but, alas, the one lesson they seemed to have learned at the Army's photo interpretation school was that the performance of "photo intelligence" work can be so vital to the success of the operation that only officers should be entrusted with this heavy responsibility. What, then, did this leave as the responsibility of these four enlisted men? Again the answer was so predictable that it should have been perceived even when the Army was developing this concept: These enlisted men should, of course, tend to the needs of the Commanding Officer and the Executive Officer, especially in making sure that the vehicle, the cameras, and the photo lab facilities were always available.

If, some 33 years later, I seem unduly exercised about this situation, I should explain exactly why: Many a brave American soldier who would still be enjoying life today was buried beneath the sod at Okinawa in 1945 because deficiencies in photo intelligence led directly to his death -- and I am prepared to stake whatever reputation I may have as a two-star Admiral on that unpleasant assertion.

Surely this sordid tale must have a happy ending. After all, history shows that the Americans won the Okinawa campaign and that at the end of it Colwell received a "citation" from the 4-star Commanding General for "bringing photo intelligence to a level heretofore unattained." But to this day I am plagued by the ambiguity of that particular episode for two reasons: (1) After all, while a "citation" can be for a good performance, more commonly it is for a poor performance (and I have received a few traffic citations in my day to prove it), and (2) the Commanding General never really did say whether the "level heretofore unattained" to which I allegedly had brought photo intelligence during the Okinawa campaign represented a new high or a new low.

And what does this ill-tempered discourse have to do with "where we are and whither we are trending" in remote sensing today? Perhaps nothing -- and perhaps everything -- depending on whether this kind of history is likely to repeat itself. In my opinion, it is indeed repeating itself in many of these unsavory aspects here and now. So if you will allow me just one more unpleasant paragraph while I am in this foul mood I will tell you why I draw this conclusion, after which I will get on to some concluding pleasantries, of which there are many.

Unless my 20-20 vision as applied both to hindsight and to foresight has failed me recently, I perceive some remarkably similar problems that are even now building up around photo interpreters (or remote sensing scientists, if you will). These problems pertain to empires to be built, rights to be protected, promotions to be achieved, grievances to be adjudicated, "Let-George-do-it" attitudes to be perpetuated and debilitating or, at the very least, distracting "fun and games" to be enjoyed -- all with little regard to whether the real job of satisfying the user's needs for remote sensing-derived information gets done or not.

To the extent that these problems are building up, history tells us that we should make vigorous efforts to solve them. The rationale for so doing, was perhaps best expressed by the famous poet-philosopher, Santellena, when he said: "Those who cannot remember the past are condemned to repeat it." It is for that reason only that I have dwelt at such length on Okinawa as one specific, and I hope highly relevant instance of an episode from the past that is well worth our remembering and learning from.

Before we conclude this section, we should emphasize that there is a far less negative way of viewing the past than has pervaded much of the foregoing discussion. In fact, the following might be considered as a parallel statement to Santellena's, except it is one which quite properly accentuates the positive rather than the negative in relation to the many historical developments that have brought remote sensing to the status that it enjoys today: "Those who can remember the past can exult in it and build upon it." Rather than feeling condemned to repeat the past, we should find it a great deal more uplifting and challenging to strive for as much progress in the next quarter century as has been achieved in the most recent one. Justification for this positive outlook will be found in the remainder of this paper.

Let us now attempt to summarize what we might conclude from this section with respect to the role of education to date in the development of remote sensing:

(1) Prior to World War II, training in photo interpretation and related fields was minimal and mostly of the "on-the-job" type, rather than as formal classroom instruction;

(2) Much of the training that was given, whether in military organizations or by private companies, was of a confidential type, designed more to reserve the technology for internal use than to promote its broad acceptance;

(3) Partly in consequence of the above two factors there was little incentive for textbooks to be written, so such books were few and for the most part, inadequate for use in the college classroom;

(4) During World War II large numbers of reservists, both in this country and elsewhere, received formal training in photo interpretation and abundant opportunity to put that training immediately into practice;

(5) For several reasons, a policy of the type employed by the U.S. Naval Reserve during that period was vastly superior to that employed by the U.S. Army Reserve, and had a far more significant impact on the post-war development and acceptance of remote sensing technology by civilian agencies. Specifically: (a) the Navy realized that the photo interpretation selectee should come from a background of training and experience in some field such as forestry, geology or engineering,that used maps which were analagous to the aerial view dealt with in military photo interpretation; (b) as a corollary, each such trainee was sufficiently qualified to be directly commissioned as an officer, with the understanding from the outset that primarily he was to do highly professional work in his photo interpretation specialty rather than to exercise distracting "command responsibilities."

(6) Following World War II, vast numbers of these reservists, upon returning to civilian life, became educators, textbook writers and practitioners and thus played a primary role in the development of the present much more sophisticated technology known as "remote sensing."

Other factors of historical significance might well be included in this section, dealing as it does in the development of remote sensing technology. However, these additional factors appear in the section that immediately follows this one because they are best incorporated in my answers to certain specific questions that I was told should be highlighted in this paper.

IV. A DISCUSSION OF SOME PRESCRIBED QUESTIONS

One question to which I was asked to address myself in this paper is this: Was the progress made with respect to the development of photography, and photo interpretation in the first 100 years (i.e. from about 1840 to 1940) too slow? The rather detailed historical account which has been given in earlier parts of this paper provides us with a basis for answering that question. Relevant factors bearing on the question include the following:

1. As compared with the present time, there were only a very few scientists of any kind during the century in question. In fact, it is reported that there are more scientists alive and at work today than have lived and died in all previous periods of the world's history combined.

2. Of that limited number of scientists, only a few few were engaged in photography-related work.

3. Communications among scientists were much more difficult to achieve then than now, with the result that a pooling of research findings was much more difficult to achieve, and

4. The development of photography depended only partly on the planning and conducting of well ordered scientific experiments. The history that has just been reviewed alludes to a few of the many chance discoveries that were made -- often as a by-product of other somewhat unrelated research. That history also shows that a photographic capability might not have been developed even yet, were it not for some happy coincidences of physics and chemistry, particularly with respect to the matching of what scientists in these fields refer to as "energy levels." In speaking of such coincidences, Tarkington of Eastman Kodak Company (Ref. 16), when slightly paraphrased, says the following:

"A quick review of the energy levels existing in latent-image formation and development will serve to emphasize the uniqueness of the process. First, there must be an empty conduction band in the crystal lattice at the right energy level above the filled band such that a photon (traveling at the speed of approximately 186,000 miles per second) can just raise an electron from the lower energy level to the upper. Then there must be a 'sensitivity speck' (silver sulfide, for instance) at just the right energy level to trap this free-roaming electron from the conduction band of the crystal, but not accept any electrons from the developing agent later. Otherwise, all crystals would develop and no image would result. The next requirement is that some silver ions in the crystal be mobile and migrate to the electron on the sensitivity speck, (the electron being obtainable only from the same crystal) and form a silver atom in situ. Finally this event, plus a few more similar ones, must change the energy level of the sensitivity speck by a suitable amount so that it now will accept electrons from the developer and so reduce the properly exposed crystal of silver halide to silver. Statistically, it appears that these events comprise a set of unique phenomena and that it is quite remarkable that these exact energy levels and energy-level differences in the silver halide crystals match those of certain chemical reducing agents. Because of this remarkable matching, it is now possible for the amplification to be on the order of a billion times, when compared to the number of photons required to produce a latent image. Furthermore, the technological processes that apply these principles in order to provide practical, convenient methods of recording radiant energy, are no less remarkable. For photography to be a success, the silver halide crystals must be (1) made by the millions in a suitable matrix; (2) modified by physical and chemical operations to provide specified characteristics; and (3) coated in a layer sometimes only 0.00001 inch thick, up to 50 inches wide and several miles long, with the thinness being controlled to 0.000003 inch for this vast area. This must be done in order to produce a radiant energy-recording system that (1) yields, to a specified level and type of radiant energy, the same results in any square millimeter of its matrix or of the matrix of a similar material made a year hence and (2) possesses the sensitivity, image quality and response to intensity variation required for the intended application."

Tarkington, one of the most knowledgeable scientists in the field of photography concluded his discourse with this "gee-whiz" type of statement: "It is no wonder that photography could not have been predicted from a consideration of the scientific principles involved, it had to be 'discovered' or 'invented'."

Since science has not yet found a way to program lucky "break-throughs," we can only conclude from the above that we would be ill-advised to assert that progress in the development of photography was inordinately slow.

A related question to which I was asked to address myself is this: Has the progress been too slow in transferring modern remote sensing technology to potential users of it? In order to provide an adequate answer to this question, we need to agree on some measure relative to the term, "technology transfer." Perhaps the best measure is that provided by Hoos et al (Ref. 17) which, again somewhat paraphrased is as follows:

"The transfer of a technology (such as remote sensing) can be considered as having been completed only when that technology, being readily available in the marketplace, becomes generally accepted practice by the user agency, and when the chief officer of that agency, upon routinely assessing all available technologies, decrees that the one in question is the one that shall be used."

As implied by the above statement, remote sensing technology will not transfer itself. Instead, there is commonly a five-stage "adoptive process" by which this new technology is perceived, internalized and used: (1) awareness (2) interest (3) evaluation (4) trial and (5) adoption. Since this process may take years, there frequently are problems in maintaining the necessary momentum, especially when there commonly are disruptions in personnel and support along the way that can undermine both credibility and morale. And even after remote sensing technology has been adopted, it still may take years before this new technology will begin to bear fruit.

In addition, the following pitfalls are likely to be encountered: (1) Oversell, (resulting in the raising of user expectations to levels beyond what current capabilities can deliver); (2) Overkill (as when the user is urged to use elaborate techniques of computer assisted analysis even when the desired information could have been derived quite adequately through the use of simple, inexpensive, and more readily understood manual interpretation techniques); (3) Undertraining (most commonly exemplified when a novice who has just completed an "appreciation" course in remote sensing is required to plunge directly into the demanding tasks that are involved in making operational use of modern remote sensing technology); (4) Underinvolvement (as when the user agency, plagued by a lack of qualified and/or motivated personnel, turns over the bulk of the work to consultants or others who lack familiarity with the user agency's resource problems, information needs, and perhaps even with the resource itself); (5) Spurious Evaluation (as when the user agency, forced by higher authority or others into a "rush to judgment" produces premature, incomplete, incestually validated, and usually overly optimistic appraisals), and (6) Misapplication (resulting in part from the sheer glamour of the shiny new tool known as remote sensing, and perhaps best metaphorized by the saying, "give a small boy a hammer, and he soon discovers that everything needs pounding").

In light of the foregoing, let us now reword the previous question to read: "To what extent are the potential users of modern remote sensing technology actually accepting it?" Since it should be clear from the preceding discussion that state and local resource managers require more than a few years to adapt, to their specific needs, a technology as complex as remote sensing, our overall conclusion is that progress is being made at a rate about as rapid as might have been anticipated or rightfully expected. Furthermore, we believe that the most substantial progress is made in those remote sensing-related projects that involve the potential users (i.e. the resource managers, themselves) throughout the entire process. Typical of the warnings that we have been given in this matter is the following excerpt from the previously mentioned report by Hoos, et al. (Ref. 17):

"Most potential users of remote sensing technology are simply unmoved by paper-and-pencil evaluation games. They recognize that externally prepared benefit-cost ratios exclude many of the considerations most important to them. They see impacts on their own decision processes, job security, and organizational behavior being overlooked and obscured behind voluminous but vacuous evaluative reports. The result for the technology developers is often an evaluative 'boomerang effect' in which users perform their own subjective assessments and conclude, for various reasons, that fruits from the technology are not worth their price."

No doubt each of the educators attending this conference is interested in conducting training programs which will not only impart information to a few more students, but provide some genuine assistance toward the goal of achieving the acceptance of modern remote sensing technology by resource managers. It therefore is appropriate to raise the question in this history-oriented paper of mine as to whether there are lessons to be learned from past experiences in this kind of endeavor.

Indeed there are, both in relation to the kind of training that is given and to whom.

With respect to the type of training, the following items are worthy of consideration:

1. Each trainee who is not already familiar with remote sensing could profit by some training in the basics of remote sensing, including the geometry of imagery, the basic matter and energy relationships that are involved in the formation of that imagery, and the kinds of equipment and techniques that can best be used in deriving information from it. A more adequate consider-

ation of this topic falls within the purview of other papers that are to be presented at this conference. Suffice it here to say that history shows us that despite the foregoing tribute to training, we can quickly reach the point of diminishing returns in presenting remote sensing merely in the form of formal classroom instruction. While much more may still need to be learned after the student has taken the equivalent, say, of a single 4-unit college level course in remote sensing (complete with laboratory exercises that entail his working on practical image analysis problems), most of the remainder may be far better learned by his conducting remote sensing research (ideally within the framework of the university and under the guidance of a professor who is a competent principal investigator for the directing of his activities). Additionally, the trainee should be given practical experience in the field in using these remote sensing techniques in an operational manner.

One of the better ways in which to ensure that the bridge is built between classroom studies and operational activities is as follows. The student, by prior arrangement, brings with him to the remote sensing lecture and laboratory sessions, some examples of imagery of an area in which he either has, or is likely to have, an operational interest. Then, before he finishes the course, he is obliged to apply what he has learned to an analysis of the imagery that he has in hand, so that he will be motivated to field check the accuracy of his interpretations and prepare a statement as to the usefulness and limitations of modern remote sensing techniques in relation to the problems that are of immediate practical concern to him. This can be a far more educational activity than if he were to devote the same amount of time and effort to the taking of some "advanced" course in remote sensing, within the confines of the university's ivy-clad buildings.

The individual who conducts remote sensing research with some specific user in mind is likely to develop a great personal interest in, and learn a great deal about, remote sensing technology acceptance. The researcher should avail himself of such a tie with a potential user whenever feasible.

A single example which continues to be of great significance in relation to the role of training and research in bringing about technology acceptance will now be given. The example is one in which we will compare the approach that was used during the 1960's by two of our federal government agencies that potentially are among the most important users of modern remote sensing technology, viz., the U.S. Department of Agriculture and the U.S. Department of Interior. Both of these Departments were allocated large sums of money during the 1960's for use in conducting investigations on the usefulness to them of modern remote sensing. The Department of Agriculture, in its enthusiasm for obtaining the highest quality of research, spent most of its appropriations in the funding of remote sensing research scientists of various universities to do the work. On the other hand, the Department of Interior placed greater emphasis on the use of its appropriations for the "in-house" performance of such work. There now seems to be general agreement as to the strengths and weaknesses of these two approaches. Specifically, it is agreed that (1) by and large the best research was done by University scientists, mostly with funding by the Department of Agriculture; and (2) by and large the best within-the-department acceptance of remote sensing technology was in the Department of Interior, primarily because of the greater top-to-bottom interest that was generated by the more highly visible "in-house" research that was conducted by that Department. The consequences of these two different approaches are still being felt within the United States and probably will be for many years to come. For example, it was essentially a "no-contest" situation when the time came for constructing a large remote sensing data center in the United States. Administrators within the Department of Interior were appreciative of the importance of remote sensing and vigorously proposed that the Department of Interior take the lead in the establishment and operation of such a center. Administrators within the Department of Agriculture were understandably less familiar with the importance of remote sensing because so little of their work had been done "in-house" where they could be constantly reminded as to both the existence of, and progress being made on, that research. At the present time, there appears to be quite general agreement that the modus operandi that was employed by the Department of Interior was preferable to that employed by the Department of Agriculture, particularly when measured in terms of progress achieved toward the goal of "technology acceptance" by the user agencies. The net effect of these two policies, in its most visible form, is the EROS Data Center of the U.S. Department of Interior. There is no counterpart to that center within the Department of Agriculture.

But let us be sure that we relate this specific example to the considerations of technology acceptance under whose mast-head it was introduced. As suggested by its very name, the Earth Resources Observation System, on which the EROS Data Center is based, is not primarily for "interior" use, but for global use. In fact, the most important products that are likely to be derivable soon from that system are globally uniform inventories of agricultural crops -- certainly such inventories are of vital concern to our U.S. Department of Agriculture, and awareness of this fact pre-dates by many years the decision as to what agency should operate an EROS Data Center. So why is the Department of Agriculture even to this day so little involved in the Center? In my opinion, it is essentially because of the relatively slow rate at which interest in, and acceptance of modern remote sensing technology has come about within that department -- as compared to the Department of Interior -- and this in turn is primarily because of the fact that in Interior, remote sensing developmental work was done mainly "in-house" while in Agriculture, such work was done primarily via the "out-house" route.

The perogative of an "elder statesman" in any field, allegedly, is to call the shots as he sees them, apparently on the presumption that (a) he has infallible insights that come only from his years of close association with that field and (b) at such a late stage in his career, what is there to lose if he disenchants certain individuals or groups through the making of profound, dogmatic and occasionally even unwarranted pronouncements and generalizations? I have been led to believe that I would not have fulfilled my responsibilities as the keynote speaker for this week-long conference of Remote Sensing Educators had I not made a few such pronouncements and generalizations. For those who disagree with me, there will be ample opportunity to rebut my remarks during the workshop sessions that are scheduled for the next several days, and also to insert any such rebuttal in the published proceedings of our week-long conference.

V. THE PROBABLE FUTURE OF REMOTE SENSING TECHNOLOGY AND TRAINING

It is deemed quite appropriate to conclude any historical review, (as this purports to be) with a look to the future. What then will be the probable future of remote sensing technology and training? For one to provide a reliable answer to that question, especially with respect to a field that is as dynamic as remote sensing, requires that he have something more than mere 20/20 vision while gazing into a crystal ball. Realization of that fact does not deter me, however, from making some dogmatic predictions. Instead, I feel much like my timber simple friend from the backwoods must have felt when he was asked a similar brow-furrowing question recently. His confident answer, after some careful reflection, was as follows: "Well, I don't know--but I'll tell ya!" Here then are some probable developments of the next few years with respect to remote sensing technology and training:

A. There will be Very Substantial Progress Toward the Development of a Globally Uniform Information System, Based Primarily Upon Remote Sensing-Derived Data.

We all are well aware that the rapid increase in both the world's population and the per capita demand for natural resources is occurring at the very time when the supply of many of these resources is rapidly dwindling and the quality of others is rapidly deteriorating. Consistent with the "one world" concept, this combination of factors creates an urgent need for the wisest possible management of such resources on a global basis. An important first step leading to such management is that of obtaining globally uniform inventories of resources. This step can best be taken if a globally uniform look at these resources can be obtained at suitably high resolution, as with an earth-orbiting satellite, and at suitably frequent intervals. Herein lies a remarkably accurate description of the look that is provided by remote sensing devices that are on board the present Landsat and Seasat vehicles. Improvements in their remote sensing packages, as already scheduled for future generations of these vehicles, will make it all the more feasible to acquire globally uniform resource inventories through analysis of the remote sensing data acquired by them.

Some advocates of a globally uniform resources information system have singled out agriculture as the field in which the greatest benefits might be derived. They look forward to the time when crop forecasting will have progressed sufficiently to permit a determination to be made, well in advance, that the northern hemisphere in some particular year is about to produce an over-abundance of oats, for example, but a serious dearth of wheat. Areas in the southern hemisphere that are capable of producing small grains are, of course, approximately six months out of phase with the grain-producing areas of the northern hemisphere. Hence the above information should be available at exactly the opportune time, so that grain growers in the southern hemisphere could be encouraged, in the instance cited above, to plant much more wheat and much less oats than they had intended, the better to balance out the global production, that year, of these two highly important crops. This is but one example of the potential improvement in the global management of natural resources likely to result from more uniform and more timely inventories of those resources.

B. There will be a Very Appreciable Reduction in the Presently Intolerable Delay Between Data Acquisition by Remote Sensing Satellites and the Supply to Users of Needed Information Derivable from Such Data.

In a companion paper to this one (Ref. 18) a tabulation appears that first indicates the frequency with which various kinds of information about resources should be made available to users and then introduces the concept of "half-life" in relation to that frequency. In so doing, the paper emphasizes that just as, in radiological research, the usefulness of an experimenter's radioactive isotope "decays" in conformity with that isotope's half-life, so the usefulness of a resource manager's information decays in conformity with a similar half-life concept. In the case of the resource manager, however, the half-life is based at least in part on how frequently a given type of information is needed by him. While the analogy is by no means perfect, it serves to highlight the importance of minimizing the delay between the time when remote sensing data is acquired and when it has been "reduced" to information that can be used by the resource manager.

C. Great Progress will be Made with Respect to the "Compression" of Remote Sensing Data.

Judging from plans that are even now developing within NASA and elsewhere, remote sensing from spacecraft in the future will entail higher spatial resolution, more spectral bands and more frequent coverage. The price to be paid for all of this is more bits of data to be telemetered from satellites to receiving stations on the ground--unless onboard computers will do much of the analysis that otherwise would be done on the ground. In that event, only the results of the analysis, rather than the initial remote sensing data, would need to be telemetered to the ground, and a much needed form of "data compression" would have been achieved.

The extent to which data compression of this type might conceivably be implemented is most clearly seen when we consider that the wise management of earth resources usually entails a three-step process: inventory, analysis, and operations.

In the inventory step a determination is made as to the amount and quality of each type of earth resource that is present in each portion of the area to be managed. In the analysis step, certain management decisions are made with respect to these resources. This is accomplished for each portion of the area by considering, on the one hand, the nature of its resources (as previously established in the inventory phase) and, on the other hand, the "cost-effectiveness" of each management alternative that might be exercised with respect to these resources. In the operations step, the resource manager implements each decision that has been made in the analysis phase (e.g., the decision to apply irrigation water to a crop that needs it, or to cut only the overly mature trees in a certain portion of the forest area, or to practice "deferred rotation grazing" in certain parts of a rangeland area).

With respect to our maximizing data compression on board a remote sensing satellite we can foresee the possibility that the technique will evolve into a highly automatic operation, in which the unmanned satellite orbiting the earth will carry multiband sensing equipment together with a computer.

Thus equipped the satellite could, for any particular area, take inventory of the resources and produce a printout that would amount to a resource map of the area. The computer could then use this inventory data in conjunction with preprogrammed factors (such as what ratio of costs to benefits that would be likely to result from various resource management practices) and could reach a decision for the optimum management of the resources in the area. The decision would be telemetered to the ground for whatever action seemed necessary.

As a simple example, the satellite's sensors might spot a fire in a large forest. Its computer might then derive information on the location and extent of the fire and could assess such factors as the type and value of the timber, the direction and speed of the wind and the means of access to the fire. On the basis of the assessment the computer would send to the ground a recommendation for combating the fire.

Capabilities of this kind need not be limited to emergencies. Many routine housekeeping chores now done manually by the resource manager could be made automatic by electronic command signals. Examples might include turning on an irrigation valve when remote sensing shows that a field is becoming too dry and turning off the valve when, a few orbits later, the satellite ascertains that the field has been sufficiently watered.

A satellite of such capabilities may seem now to be a far distant prospect. After a few more years of developing the techniques for remote sensing the prospect may well have become a reality, in which case data compression will have been developed to the ultimate.

D. Great Progress will be Made in an Area of Remote Sensing Data Reduction that is Known as "Change Detection".

Consistent with the previously mentioned "half-life" concept, the period over which the change that is of interest might have occurred may range from a few seconds to many years--from the detection and analysis of various kinds of "moving objects" (livestock for example) to the detection and analysis of various kinds of plant succession. With respect to the latter, it is instructive for us to reflect upon the amount that could be added to our present understanding of plant succession if only there were globally uniform data available, of the Landsat and "high-flight" types, that had been acquired at suitable intervals during the past 100 years or so. Remote sensing scientists of the future are certain to look back at one highly significant benchmark period, viz. the early 1970's, when for the first time most of the globe was systematically covered by such remote sensing data. Much of the change detection and analysis of the rate and direction of change that will be made by future remote sensing scientists surely will hark back to that particular benchmark period.

E. There will be a Very Significant Increase in the Amount of High-Resolution Remote Sensing Data of the Type Now Being Acquired by Various Military Satellites that will be Released and Made Available to Nonmilitary Users.

A survey of even the unclassified literature leaves many clear inferences that military remote sensing satellites can provide essentially the same resolution, in terms of "ground resolved distance" as we are accustomed to finding in the conventional 1/20,000 scale vertical aerial photographs with which most of us have worked so extensively in times past. Those who have not been privileged to work with space photography of such high resolution can scarcely envisage the extreme usefulness of it resulting from the fact that a typical high resolution space photo covers more that 1000 times as much land area as the conventional 1/20,000 scale photo and that the synoptic view of so large an area permits relationships of terrain features to be perceived that could scarcely have been appreciated from the piecing together of so many photos of the conventional type.

F. Space Photography will Largely Replace "Orthophotography", as Presently Produced, When the Need is for a Product that Provides Both the Plan View and a Large Amount of Photographic Detail.

Many features that are of interest to resource managers are far better appreciated from a study of photographic images of those features than from a map which must rely on the use of conventional symbols. Up to the present time, however, it often has been necessary to eliminate the relief displacement that is inherent in vertical aerial photographs through a somewhat costly and time-consuming process known as "orthophotography". The intent here is not to disparage the ingenious methods that have been developed for producing orthophotographs but to predict that in the near future space photographs of high resolution and low relief displacement will largely replace orthophotographs.

G. There will be a Significant Resurgence of Interest in Improving the Ability of Humans to Extract Information from Remote Sensing Data by Direct Visual Means.

It has now been almost two decades since the writing of a book called "Manual of Photographic Interpretation," under auspices of the American Society of Photogrammetry. More than 100 experts in various aspects of photo interpretation significantly contributed to the writing of that book. In so doing, they collectively provided an accurate record of what was then the "state of the art" with respect to the techniques and equipment used by humans in extracting information from remote sensing data by direct visual means. But unless my perception of developments in the field of remote sensing is grossly in error, there has been exceedingly little development during the past two decades in either the equipment or the techniques used by photo interpreters. Nor has there been any significant increase in our understanding of what makes a good photo interpreter, and therefore of the factors that should be considered in the training and selection of such individuals. For example, we know essentially the same amount now as we did two decades ago with respect to the factors that govern the photo interpreter's visual mechanism, his mental acuity, his susceptibility to fatigue and the consequences of fatigue in relation to the reliability of the information which the photo interpreter is able to derive. There has been virtually no further exploration during these two decades of the uses and limitations of "the conference system" or of "convergence of evidence" as applied to photo interpretation, nor of the use of such aids as photo interpretation keys, sound recorders, or enumerator's pencils. Temporarily, at least, these important aspects have been forgotten because of our pre-occupation with the marvels of modern day remote sensing, including opportunities for computer analysis rather than human analysis of remote sensing data. Now that most of the cream appears to have been skimmed from this new technology, there almost certainly will be a renewed appreciation of the need to facilitate the extraction of information from remote sensing data by humans.

H. There will be Increased Efforts to Define the Roles of Humans and Machines as They Function as a Team in the Derivation of Information from Remote Sensing Data.

Remote sensing scientists are beginning to acquire a far greater appreciation than heretofore of both the uses and the limitations of machines in relation to the acquisition and analysis of remote sensing data. One encouraging sign is to be found in the fact that the machine analysis of remote sensing data is rarely referred to any more as "automatic data processing." Instead use is made of the more aptly descriptive term "Computer assisted analysis."

The following point is "key" to our appreciation of the uses and limitations of computers in the analysis of remote sensing data: If a computer is to provide meaningful assistance in the analysis of remote sensing data, usually the data must be in numerical form. Alternately stated, in most instances if the input is not in the form of digits then, to quote the robot, "it does not compute." On the other hand a human, in making his analysis of remote sensing data relies not on digits but on such photo image attributes as size, shape, shadow, tone, texture, site, pattern, and association.

Of all such attributes, tone stands out as the one which can be far more easily and meaningfully digitized than any of the others.

Let us now, just for a few moments, outdo even the most ardent computer worshippers by giving a heart and mind and soul to the components of a computer-based system designed for the acquisition and analysis of remote sensing data. For example, let us temporarily dignify in this way the remote sensing device known as a "line-scanner" or "optical mechanical" scanner, since it contributes, at least to some extent, a replacement for the conventional camera-film-filter system.

First off, the optical mechanical scanner (and its matching system for data analysis) arrogantly rejects all of the previously mentioned photo image attributes except tone, which it prefers to call "scene brightness." It also rejects the conventional "grey scale" that is used by humans in the analysis of tone and uses instead a digital grey scale range of, say, 128 digits. Realizing that there is strength in numbers but that even this many numbers may not be sufficient, this scanner joins forces with scanners that operate in other parts of the spectrum, happy to consider itself merely as one element of a marvelous remote sensing system known as a "multispectral scanner." Now it can legitimately claim to do great things because such an assemblage of components can go much farther in revealing the full "spectral signatures" of various kinds of features. Furthermore, since all of these signature elements, as acquired by the multispectral scanner, can be digitized, they lend themselves to computer programming and, in due time, to a form of computer analysis that can lead to the identification of features in a way that could scarcely be duplicated by a mere human. Up to this point all is well in that this assemblage of machinery is merely exploiting the following principle of physics that deals with basic matter and energy relationships (Ref. 19):

> The reflectance, emission, transmission, and scattering of electromagnetic energy by any given kind of matter are selective with respect to wavelength of energy and specific for any given kind of matter, depending primarily upon its atomic and molecular composition.

But this statement serves to highlight the fact that, in its enthusiasm for recording "scene brightness," the scanner has unnecessarily limited itself to the recording, pixel-by-pixel, of scene reflectance. Why not do the same for scene emittance, for example, by building into the scanner system an additional capability--namely a thermal sensing capability? And so the thermal infrared component of the multispectral scanner is born. And, speaking of reflectance, why not exploit this attribute to the fullest through the use of a laser beam that will illuminate the scene with extreme brightness at some additional and highly specific wavelengths--especially at wavelengths that will give to this ever-growing sensor system an all-weather day-and-night capability? And so various active systems, including one highly successful one known as "SLAR" (for side-looking airborne radar) have been born and greatly improved upon in recent years.

Surely at some point this ever expanding sensor and data analysis system (to continue the personification of it just a bit further) starts to suffer from "delusions of grandeur." That becomes increasingly apparent when we note, for example, that it is starting to refer to itself as a "sophisticated system" that is well on its way to becoming a "multi-thematic mapper."

For purposes of this paper, at least, let us end this personification of machines, even though some timid humans seem to go much farther than this without realizing it. (An example is the remote sensing scientist who recently was explaining to me--"And then I say to the computer, would you please provide me with a print-out of . . . etc."). Certainly at this point it is high time for the human to reassert himself, recognizing that the remote sensing system--and the computer on which it dumps its data--were designed by man and should serve at the pleasure of man--never the other way around. It also is time to remind ourselves that, with all of their sophistication, these machines thus far have been able to exploit signficantly only one attribute, namely "tone" or "scene brightness" from the previously mentioned arsenal of remote sensing image attributes that are routinely exploited by human photo interpreters.

Now that we have placed the human back in the saddle again, where he belonged all the time, we may find it fruitful to ask whether there are image attributes other than tone that lend themselves to digitization, and hence to computer assisted analysis. At the present time the short answer is "no"--at least in my opinion. As justification for that answer may I remind you that, in at least the past two decades, many highly competent scientists have, with only limited success, attempted to assign digital signatures to the shapes of features (as perceived by remote sensing) through use, for example, of the "area-to-perimeter ratio." Similar efforts have been made to describe image texture with digits through use, for example, of microdensitometer traces made across remote sensing-derived images of various textures. Numbers conceivably could be assigned to such texture-related measures as the frequency, the amplitude, and the shapes of peaks and valleys--all as obtained from the microdensitometer traces. But I find myself in complete agreement with the innovative giants of this particular field of endeavor when they assert that they still have a long way to go before digits can do justice to texture analysis or, in fact, to any of the previously mentioned image attributes except tone.

The foregoing may seem to give short shrift to some moderately successful efforts that have been made to analyze the spatial arrangements that machines can detect when they analyze the digital values of different aggregations of pixels as acquired by the LANDSAT MSS system (e.g., 4x4 and 8x8 aggregations). Such efforts have entailed the use of both Fourier Analysis and Hadamard Transform techniques. Results to date of these efforts suggest that (1) in the future, computers (properly programmed) may be able to analyze spatial arrangements and delineate stratum boundaries moderately well, after all, using MSS data as the input, but (2) major problems frequently will arise because of the fact that the computer is so "literal" that it cannot cope with anomalies encountered in a given stratum, even though the human would have little difficulty in disposing of such anomalies.

I. There will be a Better Realization that the Feasibility of Using Remote Sensing Techniques in Any Geographic Area Depends on Whether that Area is Simply or Complexly Structured.

Table 2 is an attempt to set forth some of the characteristics of simply structured versus complexly structured areas in relation to the

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Table 2 Characteristics of Simply Structured versus Complexly Structured Areas in Relation to Natural Resources

SIMPLY STRUCTURED AREAS	COMPLEXLY STRUCTURED AREAS
A. Agricultural Vegetation	A. Agricultural Vegetation
1. Fields large, regularly shaped, usually homogeneous with respect to crop condition.	1. Fields small, irregularly shaped, frequently heterogeneous with respect to crop condition.
2. Few competing crops and cultural practices.	2. Many competing crops and cultural practices.
3. Little interspersion of cropland with non-cropland.	3. Much interspersion of cropland with non-cropland.
4. All fields of a given crop planted on about the same date and hence developing in essentially the same seasonal pattern.	4. Fields of a given crop planted on many different dates and hence developing with many different seasonal patterns.
B. Range and Forest Vegetation	B. Range and Forest Vegetation
1. Blocks of rangeland and forestland are large and relatively homogeneous.	1. Blocks of rangeland and forestland are small and relatively heterogeneous.
2. Elevational range is low to moderate and hence vegetation of a given type tends to develop with essentially the same seasonal pattern.	2. Elevational range is high to very high and hence vegetation of a given type tends to develop with many different seasonal patterns.
3. Few vegetation types present, all adapted to the same elevational and climatic range.	3. Many vegetation types present, each adapted to a particular elevational and climatic range.
4. Topography flat to gently rolling so that few vegetational differences are the result of differences in slope and aspect.	4. Topography steep so that many vegetational differences are the result of differences in slope and aspect.
5. Cultural practices with respect to range and timber resources are few and uniform.	5. Cultural practices with respect to range and timber resources are many and varied.
C. Geology, Soils, and Hydrology	C. Geology, Soils, and Hydrology
1. Geologic, soil, and hydrologic formations are relatively large, simple, discrete, and homogeneous.	1. Geologic, soil, and hydrologic formations are relatively small, complex, intermingled, and heterogeneous.

feasibility of making remote sensing-based inventories. Such characteristics apparently have been given little consideration by remote sensing scientists up to the present time. As a result there have been some seriously mistaken estimates made in the recent past as to the feasibility of using remote sensing techniques in various geographic areas.

The emphasis in Table 2 is placed primarily upon such renewable resources as agricultural crops, range vegetation, and forest vegetation; only limited treatment is given there to whether the geology, soils and hydrologic resources of an area make it a simple- or complexly-structured one. Consistent with the so-called "land systems" concept, however, (as developed, for example, by Christian and Stewart for use in Australia), an area that is of complex geologic structure is very likely to be complex also in terms of its soils and hydrologic attributes and therefore in its associated vegetative attributes.

The photo interpreter is likely to perceive these attributes in reverse order because, in most areas, the vegetative attributes are most photogenic and hence are most easily perceived. Stating the matter in reverse order, therefore, it is highly probable that when the vegetation attributes of an area are found to be complex, the geology, soils and hydrologic attributes of that area are complex also. As a result, the feasibility of using remote sensing-based techniques for the inventory of such an area's entire "resource complex" is likely to be considerably more limited, and the requirement for acquiring ancillary "ground truth" data much greater, than if the area were more simple structured.

As I look to the future I predict a growing realization by remote sensing scientists of the fact that there are fundamental differences, of the types suggested by Table 2, among various geographic areas. If so, when such scientists are attempting to make an extension of "remote sensing feasibility ratings" from any particular test area to other areas, they will take far more cognizance of these differences in the future than they have in the past.

J. There will be a Better Realization that the Feasibility of Using Remote Sensing Techniques can be Assessed in Terms of Several Other Considerations Also.

Table 3 seeks to list all of the major factors which govern the potential usefulness of any given type of aerial or space photography to those who wish to inventory, develop, and manage an area's natural resources. The potential significance of such a table in relation to our discussion of the future of remote sensing is indicated by its accompanying explanatory notes.

Consistent with the note appearing at the top of that table there can be for each of the listed factors, an entire "spectrum" of conditions, ranging from very favorable to very unfavorable, in relation to the usefulness of remote sensing. However, in any given instance, the relevant factors probably can be assessed reasonably well, and even quantified, if only we will make the effort to do so. If so, the overall usefulness of remote sensing will be determinable quantitatively by the aggregated effects of these various factors. In any specific instance, however, it probably will be necessary to assign a weight to each factor, in proportion to its estimated importance. Ideally, then, it will be this single aggregated value that will accurately indicate "remote sensing feasibility."

As emphasized by the note appearing at the bottom of Table 3 the statements appearing in the left column of that table are descriptive of

Table 3.—Factors which Govern the Potential Usefulness of any given Type of Aerial or Space Photography to Those who wish to Inventory, Develop, and Manage Natural Resources

Note: For each of the factors listed in this table an entire "spectrum" of conditions is theoretically possible, ranging from very unfavorable to very favorable as regards its effect on the usefulness of the given type of photography in relation to the inventory, development, and management of natural resources. However, in any given instance, the applicable situation is likely to be well locatable and quantifiable. It follows that, in any given instance, the overall usefulness of this type of photography for the stated purpose will be determinable quantitatively by the aggregated effects of these various factors. Usually, however, a weight will need to be assigned to each factor, in proportion to its estimated importance; hence the aggregated value normally will reflect these individual weights.

1. Area to be analyzed is very complexly structured in terms of the criteria appearing in Table 2.	1. Area to be analyzed is very simply structured in terms of the criteria appearing in Table 2.
2. Only photos having a GRD of, say, 10 feet are available for use.	2. To the extent desired, photos having a GRD of, say, 10 feet plus any or all other forms of remote sensing can be used.
3. Clouds usually obscure the area that is to be analyzed.	3. Clouds rarely obscure the area that is to be analyzed.
4. Remote sensing can only be done on one date and at one time of day.	4. Remote sensing can be done on each of many dates and at many times of day.
5. There is a very long delay after the photos have been taken before they can be retrieved and placed in the hands of analysts.	5. There is only a very short delay after the photos (and other remote sensing data) have been obtained before they are retrieved and placed in the hands of the analysts.
6. Because of rigid time constraints, only a "quick look" analysis can be made.	6. For all practical purposes there are no time constraints; hence the making of a complete data analysis is feasible.
7. Only one data analyst is available and he is inexperienced, poorly trained, poorly funded, poorly equipped, little appreciated, and poorly motivated.	7. An entire multidisciplinary team of analysts is available and each of them is well experienced, well trained, well funded, well appreciated, well supported by consultants (when they are needed), and well motivated.
8. The analysis required is limited to only one natural resource and consists of a one time inventory of it in its static state.	8. The analysis required is one which will integrate all components of the entire "resource complex," including renewable resources, and will make repeated inventories to monitor them in their dynamic state.
9. The resource classification scheme that is used is of limited extensibility because it is locally specific.	9. The resource classification scheme that is used has great extensibility because it comprises one component of an overall scheme that is globally uniform.
10. The derived inventory data must be tightly held because of sensitivities that relate to the economic or military security of the area under study.	10. The derived inventory data can be made freely available to all interested parties without fear of economic or military sensitivities.
11. The sole purpose of obtaining the inventory data is to facilitate resource preservation.	11. The multifaceted purpose of obtaining the inventory data includes the facilitating of resource development.
12. Few funds are available with which to implement decisions derived from a study of the resource information that has been acquired; furthermore the decisions themselves are suspect because they were based on inadequate information as to the cost-effectiveness of each of several resource management alternatives.	12. Very substantial funds are available, and with them the necessary equipment, engineering knowledge, and local political stability, to ensure that both short-term and long-term benefits will derive from implementation of the resource management decisions; furthermore the decisions themselves are sound because they were based on reliable information as to the cost-effectiveness of each of several resource management alternatives.
Note: To the extent that the factors listed in the above column pertain, there will be minimum benefit derived from the use of this type of photography in relation to the inventory, development, and management of natural resources.	Note: To the extent that the factors listed in the above column pertain, there will be maximum benefit derived from the use of this type of photography in relation to the inventory, development, and management of natural resources.

highly unfavorable situations. Hence, to the extent that those descriptions apply in any given instance there will be minimum benefit derived from the use of remote sensing techniques in relation to the inventory, development, and management of natural resources. In contrast, the statements appearing in the right column of that table are descriptive of highly favorable situations. Hence, to the extent that those descriptions apply in any given instance, there will be maximum benefit derived from the use of remote sensing techniques.

While the statements appearing in Table 3 could be improved and expanded upon, they should suffice, even in their present form, to make the desired point in relation to the theme of my paper, namely, that remote sensing scientists will give far more attention to such considerations in the future than they have in the past, and with the following beneficial result: There will be far less overselling of remote sensing techniques for situations where they are not likely to be successful, and there will be far more extensive and intelligent use of remote sensing techniques in situations whether they have the potential for being highly successful.

At the risk of overstating the matter I will assert that, in the long run, it is the giving of proper consideration to statements and factors such as those listed in Table 3 that is at the very heart of remote sensing technology transfer and acceptance in the years to come.

K. There will be a Greater Borrowing by Future Remote Sensing Scientists of Various Applicable Techniques and Procedures that Have Been Developed in Other Disciplines.

In any discipline that is relatively new and fast-growing there is likely to develop the belief that each problem encountered is an entirely new one, the likes of which have never before been encountered by man or beast. Again, if my perception is correct, remote sensing is among the disciplines that have suffered from this belief--one that employs the "not-invented here" syndrome in rejecting worthy contributions from other disciplines. It is entirely probable that at this very moment many of the problems that remote sensing scientists are seeking to solve have already been solved, in only a slightly modified context, by workers in other disciplines. To the extent that this is true we should even now be testing the applicability to remote sensing image analysts of (1) various search techniques used by astronomers or microscopists as they attempt systematically to search for information; (2) various counting or enumeration techniques used by doctors in determining the number of red and white blood corpuscles in a patient's blood sample; (3) various fatigue-reducing techniques used by industrial supervisors to ensure that their workers who are engaged in highly repetitive tasks will perform acceptably well throughout an 8-hour work day; and (4) various "convergence of evidence techniques" used by lawyers to maximize the prospect that a deduction made is the correct one.

Such a mass borrowing of information and techniques from other disciplines should not be regarded as a shameful practice, but as a highly intelligent one. For those remote sensing scientists who nevertheless might suffer pangs of conscience from engaging in this practice, adequate consolation should be found in the following thought: For each field or discipline from which remote sensing scientists might borrow information of the types indicated above (and for many other fields as well) repayment many times over is likely to be offered in the near future--the reciprocity in this case being in the form of remote sensing derived information that could be used to great advantage in these other fields or disciplines.

One of the first to express, in highly positive terms, this concept of mass borrowing of information as a means of progressing toward the desired result, was Aristotle, who reportedly said some 2400 years ago: "The search for truth is in one way difficult and in another easy, for no one can master it fully nor escape it wholly; yet each, through his own efforts, adds a bit of information, and from the mass of knowledge thus assembled there arises a certain grandeur."

L. "Synthetic Stereo" Will be Used to an Ever-Increasing Extent as an Aid to the Interpretation of Space Photography.

The lack of relief displacement in a space photograph is a blessing when we wish to have a near-orthophotographic record of the landscape. Axiomatically, the lack of relief displacement is the very attribute that most limits the interpretability of a space photograph when the objective is to identify, from their three-dimensional configurations, certain important features that are of interest to the managers of natural resources. The remedy to this deficiency as applied to terrain features that are of sufficient size to be clearly resolvable on the space photograph is to be found in a form of "synthetic stereo" that can be produced for any area that already has been topographically mapped to a suitably small contour interval.

M. "Shadow Parallax" Also will be Exploited in the Future as a Means of Perceiving on Space Photographs the Three-Dimensional Characteristics of Features.

Interest in this technique also stems from the lack of relief displacement in a space photograph. Depending upon the resolution of the space photography the technique can be applied to mountains, buildings, or even trees. If two photos are taken of the same area, but at different times of day, (e.g., one hour before noon and one hour after noon, local sun time) and then viewed through a stereoscope the shadows will be seen to have shifted their positions. Furthermore, the taller the object the greater the shift will have been. As seen through the stereoscope the apparent heights of the shadows are indicative of the actual heights of the objects casting them. Illustrations of this technique appear in Chapter 2 of the Manual of Photographic Interpretation (Ref. 2).

N. Future Improvements in Sensor Capabilities and Resource Classification Schemes will Better Conform to the Requirements Imposed by Resource Policy Decisions and Management Objectives.

In an earlier section of this paper some consideration was given as to the kinds of information, both basic and applied, that might be desired by those working in various resource-related disciplines. In the present section let us build on those considerations by acknowledging that either of two approaches might be used as we seek to relate remote sensing capabilities to user requirements. In the first approach, remote sensing capabilities would be considered at the outset and, in the light of these capabilities, an exhaustive list would be compiled showing all the kinds of information that might be attained through the full exercise of these capabilities. Then due consideration would be given to each item on the list in order to determine whether that item might conceivably satisfy some user's informational requirements.

In the second approach, a list of economically significant or otherwise important user requirements for information would be compiled. Once the list had been compiled, consideration would be given to the various remote sensing capabilities in an effort to determine which of these requirements might be met and by what remote sensing process.

If either of these two approaches were to be used, however, consideration would eventually need to be given to the best compromise between user requirements and remote sensing capabilities. For example, if under the second approach, it were found that one of the desired items of information could not be directly obtained by means of remote sensing, the investigator should consider whether the requirement might be so modified as to make acceptable to the user some alternate kind of information which could, indeed, be derived through the remote sensing process.

As indicated by Figure 1 it is sometimes helpful to consider that there are several links comprising the chain of events by means of which remote sensing techniques can be used to satisfy the information requirements of various resource management groups.

On the one hand, the "hardware oriented" person is likely to use the first of the two approaches, viewing the matter as proceeding from the left links of the chain forward and to the right. On the other hand, the "management and policy" oriented person is likely to use the second approach,

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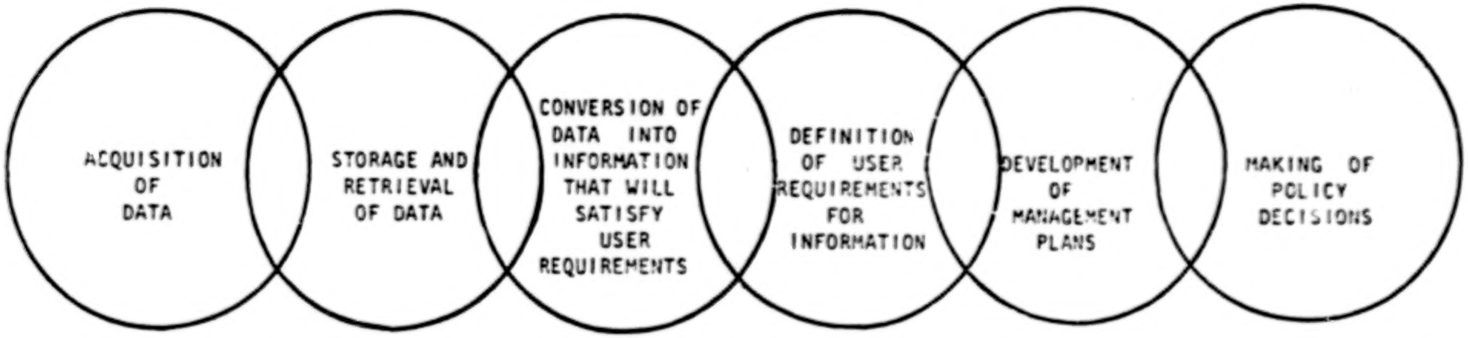
ACQUISITION OF DATA
STORAGE AND RETRIEVAL OF DATA
CONVERSION OF DATA INTO INFORMATION THAT WILL SATISFY USER REQUIREMENTS
DEFINITION OF USER REQUIREMENTS FOR INFORMATION
DEVELOPMENT OF MANAGEMENT PLANS
MAKING OF POLICY DECISIONS

Specify spectral and spatial resolution characteristics of sensors, atmospheric constraints, target illumination and weight, power and volume requirements of the sensors. Specify performance characteristics of vehicles needed to transport sensors, including speed, attitude control, service ceiling, stay time and ability to satisfy weight, power and volume requirements of the sensor package.

Specify the "model" or "models" that will best facilitate the storage of data and its retrieval periodically by those who are to convert the data into information that will satisfy specific requirements of the various users.

Establish the "signature" for each type of earth resource feature that is to be identified, as a function of its spectral, spatial, goniometric and temporal characteristics. By proper use of humans and ADP machines, provide an "in-place" delineation, area-by-area, of each type of earth resource, including vegetation type, soil type, water quantity and quality, topography, culture, and multi-resource interrelationships.

Precisely define the kinds of earth resource information needed by those who must develop and implement management plans and policy decisions; also define the speed with which these types of information must be provided following acquisition of remote sensing data, and the frequency with which these kinds of resource information are likely to be needed by the various users.

Determine, for example, how best to manage the watershed with a view to multiple use management; also how and where to store water and to develop and distribute hydroelectric power from it. Also, how best to transport water to farmlands, urban areas and other places of water consumption.

Determine, for example, whether to encourage or discourage (1) the growth of a megalopolis in a particular area, (2) the intensification of agriculture in a second area, etc.

Figure 1 Links by means of which remote sensing techniques can be used to satisfy the information requirements of various resource management groups.

viewing the matter as more logically proceeding from the right links of the chain backward and to the left.

Up to the present time the first approach has predominated, even from the days of the first experiments in space photography when the weight, power, and volume requirements of available sensors dictated what the sensor package would be that might be privileged to fly "piggy-back" on the next space shot. But we can predict with confidence that in future space shots, especially those in which the satellite is specifically dedicated to the collection of resource-related data, both the sensor capabilities and the resource classification schemes will be far more responsive to the information requirements of the types suggested in Figure 1, as imposed by resource policy discussions and management objectives.

In Figure 2 a diagram is presented which illustrates this "links of a chain" concept in a quite different way, and in somewhat more specific terms. The example dealt with in that figure is one in which the objective was to maximize the usefulness of remote sensing in satisfying the informational requirements of water resource managers in the state of California. With respect to that example, the "hardware oriented" individuals, in conformity with the first approach, would view the matter as progressing from bottom to top in this diagram. It is very clear, however, that state and regional planners, being "policy oriented" individuals, and also being concerned not just with water but with the entire resource complex, would view the matter as progressing from top to bottom.

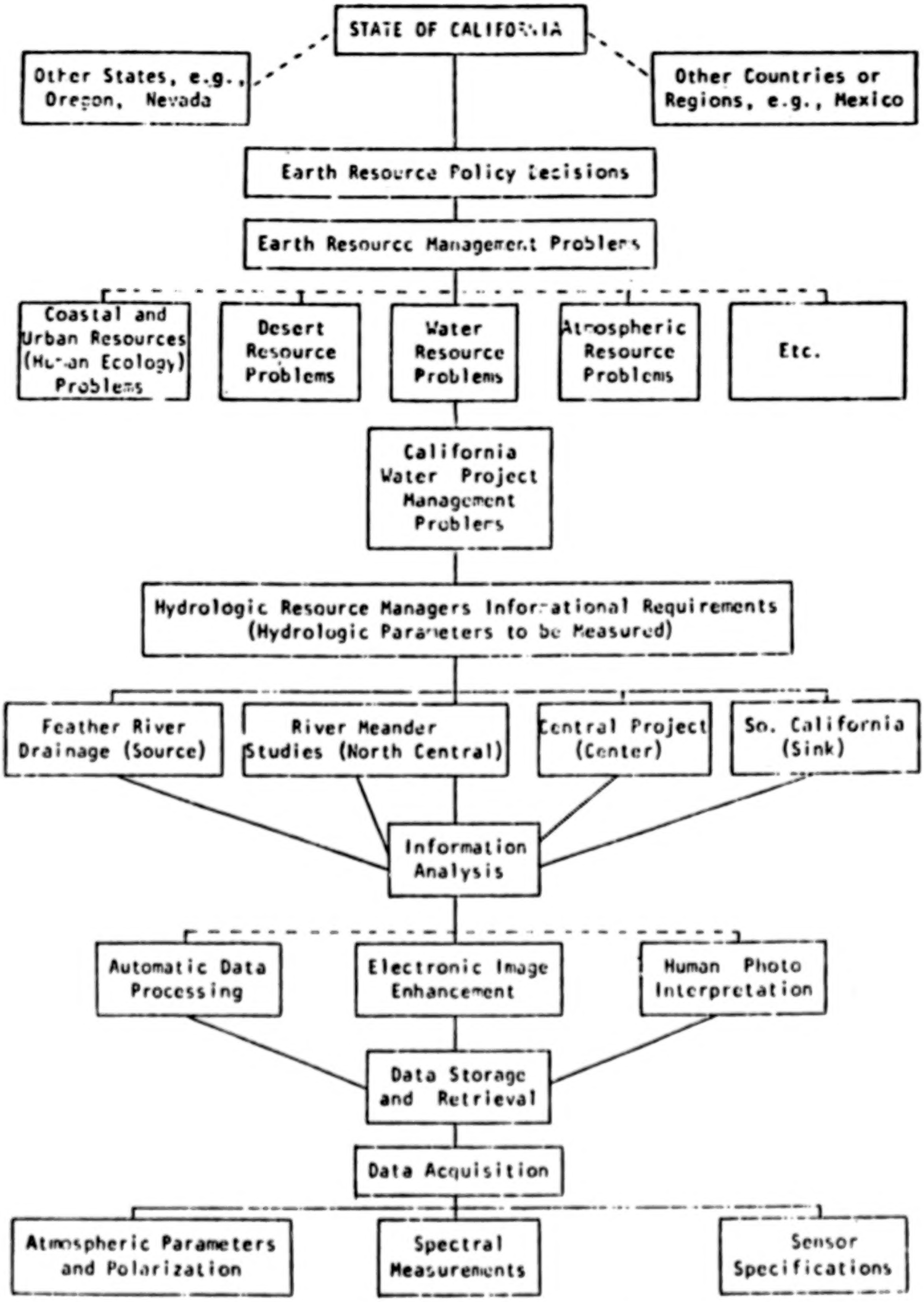
STATE OF CALIFORNIA
Other States, e.g., Oregon, Nevada
Other Countries or Regions, e.g., Mexico
Earth Resource Policy Decisions
Earth Resource Management Problems
Coastal and Urban Resources (Human Ecology) Problems
Desert Resource Problems
Water Resource Problems
Atmospheric Resource Problems
Etc.
California Water Project Management Problems
Hydrologic Resource Managers Informational Requirements (Hydrologic Parameters to be Measured)
Feather River Drainage (Source)
River Meander Studies (North Central)
Central Project (Center)
So. California (Sink)
Information Analysis
Automatic Data Processing
Electronic Image Enhancement
Human Photo Interpretation
Data Storage and Retrieval
Data Acquisition
Atmospheric Parameters and Polarization
Spectral Measurements
Sensor Specifications

Figure 2 Diagram illustrating the structure of one particular remote sensing project, (viz. one which seeks to use remote sensing to satisfy the informational requirements of California's water resource managers), and its relation to other critical resource problems in California and elsewhere. The "links-of-a-chain" concept expressed in Figure 4 also is apparent here.

O. Intelligent Exploration of the "Multi" Concept Will Greatly Increase the Amount of Information Derivable Through the Use of Modern Remote Sensing Techniques

In chapter 1 of Reference 4, there is a fully illustrated presentation of what is called there (for want of a better term), the "Multi" concept. The reason for assigning that term (at least tentatively) to the concept, is suggested in Figure 3 of the present paper, wherein many of the elements of that topic are listed and inferentially defined. Even a cursory examination of Figure 3 is likely to suggest two thoughts to the reader: (1) In the interest of completeness several other components might be added to those already listed there, and (2) If a remote sensing scientist were to insist on using all of these components on all remote sensing-related projects, he should very properly be discredited on the grounds of being "multi" happy. Perhaps it is in consideration of these two thoughts that we arrive, on balance, at the following conclusion: In the future it will indeed be possible, through intelligent and properly restrained use of the "Multi" concept, to increase significantly the amount of information derivable through the use of modern remote sensing techniques.

1. More information usually is obtainable from multistation photography than from that obtained from only one station.*
2. More information usually is obtainable from multiband photography than from that taken in only one wavelength band.
3. More information usually is obtainable from multidate photography than from that taken on only one date.
4. More information usually is obtainable from multipolarization photography than from that taken with only one polarization.
5. More information usually is obtainable from multistage photography than from that taken from only one stage or flight altitude.
6. More information usually is obtainable through the multienhancement of this photography than from only one enhancement.
7. More information usually is obtainable by the multidisciplinary analysis of this photography than if it is analyzed by experts from only one discipline.
8. The wealth of information usually derivable through intelligent use of these various means usually is better conveyed to the potential user of it through multithematic maps, i.e., through a series of maps, each dedicated to the portraying of one particular theme, rather than through only one map.

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* The term "multistation photography" (not to be confused with "multistage photography") pertains primarily to successive overlapping photographs, taken along any given flight line as flown by a photographic aircraft or spacecraft. When two such photographs are studied stereoscopically, the photo interpreter is better able to perceive features than if a photo from only one of the two stations was available.

Figure 3: The "Multi" Concept: For further explanation, see text.

SUMMARY AND CONCLUSION

In this paper we have discussed the history and future of remote sensing technology and education under five major headings:

(1) a historical review of the discovery and development of photography and related sciences;

(2) remote sensing progress during the past quarter century;

(3) the role of education to date in the development of remote sensing technology;

(4) a discussion of some prescribed remote sensing questions; and

(5) some predictions with respect to the future of remote sensing technology and training.

From this discussion, we conclude that:

(1) those of us who are currently engaged in remote sensing activities enjoy an unusually rich heritage that results from roughly equal amounts of the following ingredients on the part of our predecessors: dedication, hard work, brilliant innovativeness and good luck;

(2) while the hey-day for remote sensing-related research may be fast coming to a close, the potential pay-off from this research is only beginning, especially among the various federal, state and private agencies that need better resource inventories as the first step leading to better resource management; and

(3) consequently, there will be a continuing and expanding need during the foreseeable future for training in remote sensing principles, techniques and applications -- training of the type that is best provided at colleges and universities by individuals such as have been assembled here for this Conference of Remote Sensing Educators. I, therefore, think that we all can look forward enthusiastically to the prospect that this will be a most timely and highly productive conference.

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Is Remote Sensing Far Out?

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Titles of speeches, like Executive Summaries, often have only a tenuous relationship to the subject at hand. The title of my talk this evening is an exception; it pertains directly to the matter I plan to discuss. I will, however, admit that, as put, the question is academic, a fact which should render it appropriate to this audience, but which also carries the implication that there is no definitive answer. If I admit, further, that, coming from me, the question is loaded and that I have a bias, then I have conformed to the first canon of professional research and fended off the possible criticism that I am biased. I know; I said it first.

Whether one thinks remote sensing is far out and how far out one considers remote sensing to be depends in large part on one's *perspective,* and perspective depends to a great extent on one's position on the learning curve. This is to say, then, that perspective and education are related in interesting ways.

For example, it might seem far out to claim a relationship between Parkinson's Law and remote sensing and yet, it was through his World War II experience in the British Army that C. Northcote Parkinson evolved the basic law of bureaucracy, viz., that work expands to fill the time available for its completion. He tells it this way

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> Somebody is needed to interpret aerial photographs, so a private is assigned to the job and given a corner desk. He snaps to attention, says, "Very good, Sir," and sits down. Two days later he is back complaining that he needs another man because there are so many photographs and that if he's to have any authority over his helper, he'll have to be a lance corporal. "I quite see that; yes, yes," says the officer. In three months, he has a staff of 85, he's become a lieutenant colonel, and he never sees a photograph because he's so busy tending to administration [1].

Lest my NASA friends become uneasy about the possible implications of this bit of serendipity, I hasten to point out that it is the universal applicability of the Law that has kept it viable for the past twenty years and that insures its durability in the future. The relationship to space is only a matter of historical coincidence and used here to prove the point that, as with so many contributions of remote sensing, consequences ripple far and beyond the original source.

Having shared this vignette and, I hope, made my point, I shall return to the business at hand, which is to find an answer to the question, "Is remote sensing far out?" In true academic form, the response is several more questions:

(1) What is the perspective?

(2) Whose perspective is it?

(3) On what does the perspective depend?

And herein lies a liberal education in psychology, sociology, political science, economics, resource management, and even poultry husbandry, since the chicken-and-egg dilemma is often encountered in Landsat application. (Before it can become operational, the system must have a constituency of users and supporters; users are not likely to become a staunch constituency until they are convinced that Landsat will be an operational system.) Moreover, much of the usefulness of this and related technologies will depend on educated and competent people, but we cannot have them until we develop them. This suggests an expansion of the role of educators who have been inclined to limit their activities to teaching technique.

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[1] A. Flora Lewis, "After 2 Decades, C. Northcote Parkinson Finds His Law is Still Inexorable", The New York Times, June 19, 1978.

What, then, are some of the more commonly encountered perspectives that delimit our spatial relations with remote sensing (i.e. whether we regard it as "far out" and how far)? One is the *get-a-horse syndrome;* this maintains a pessimistic posture on any technological advance. It is so named bacause it is derived from the advice given Henry Ford by the sceptics. They said that his invention wouldn't fly! Antedating them by many years were the Luddites, their fame in history due to the word they contributed -- *sabotage,* for the wooden shoes (sabots) they hurled into the textile machinery. Sometimes, impediments are more subtle, as when current practice is valued because "it is the way we've always done things", or because new methods upset the comfortable even though archaic horse-and-buggy ways.

If the perspective is one of resistance, then logic dictates that it can be allayed if not dispelled by tracing the path of its cause. NASA has learned through long years of experience with such programs as spinoff, technical utilization, and now technology transfer that reasons for resisting new and advanced techniques are myriad and complicated. Frequently, they stem from the social environment and reflect the climate of receptivity, with only an attenuated relationship to the technology itself. Thus, resource managers may recognize the potential of remote sensing as a tool and yet be deterred for reasons bureaucratic, institutional, or politic from incorporating it in their workaday routines.

Another perspective comes under the heading of *the fast abacus*. This view appraises any technique solely from the viewpoint of getting the same old jobs done cheaper and faster. The early electronic computer system, designed to meet only current paper-processing needs, was an example of this view, and went the way of the Edsel. Designs which met needs as yet unperceived gave this revolutionary technology its tremendous impetus. The point has been made with respect to the development of the automobile that public expectation always ran ahead of the technology. Therein may be a lesson apropos to remote sensing: instead of trying to harness the space effort to our little red wagons, we should hitch our wagon to the stars. In other words, we should expand our perception to learn how the view from space can enhance our ability to manage earth's valued and finite resources. The launch of Seasat just this week is less a challenge to the engineers who created it than to the scientific and academic community upon whom it is incumbent to make intelligent use of its information-gathering potential. With Seasat as with Landsat, we *can* know more, the question is, *will* we?

The point is of paramount importance for educators to ponder. Their perception of their own role is vital in the ultimate utilization of the technology. Not only is their research crucial, for it is in their laboratories that the experimental applications take form and "glitches" are discovered and corrected, but the "human output" of their teaching constitutes the reservoir of competent leadership in the future. The mission of education would benefit from clarification: it should include not merely how to derive data from satellite imagery but how and where it can be applied. In this sense, the education community's role would be that of communicator, forging a link between tomorrow's technical specialist and tomorrow's user. Just as remote sensing interfaces with many disciplines, such as forestry, water resources, agriculture, and the like, and, ultimately, impinges on decisionmaking in a number of sectors and at different levels, so should the background and training slice across the traditional academic boundaries and reach the students of public administration and planning -- the policy makers of the future.

That the prevailing pattern, with notable exceptions, is a manifestation of the myopic perspective that sees remote sensing primarily as a vehicle for pursuing a pet project and/or acquiring some hardware cannot be gainsaid. Perhaps this attitude can best be understood when one considers the administrative and bureaucratic strictures that delimit faculty's degrees of freedom. Stringent budgetary conditions, quantum leaps in laboratory costs, and the fiscal malaise created by a tax-conscious public -- all have contributed to a climate of uncertainty on the nation's campuses. Government agencies, for their part, are under pressure to deliver evidence that dollars have been well spent and make demands not always compatible with the universities' *modus operandi*. If the relationship between federal funding agencies and the country's universities is one of continuing but uneasy detente, it can be said that there are nonetheless elements of *entente cordiale* emanating from the personal rapport that exists among members of the academic community and government officials. Missions are accomplished not by flow charts and program schedules but by human dedication and commitment shared by both sectors.

A state of institutionalized myopia is imposed by the very principles of management science almost universally accepted from county to Congress. When President Johnson decreed that all federal agencies adopt the Program Performance Budget System (PPBS), he was merely reflecting a trend that had persevered before and prevails long after the mandate was officially rescinded [2]. (As in the war in Vietnam, so in the War on Poverty, the PPBS concept in its various manifestations produced no remarkable victories.) The core and common element of the tools of management science, variously known as systems analysis, operations research, PPBS, and more recently, technology assessment and risk analysis, is the cost/benefit analysis. Actually, the cost/benefit ratio is as old as the hills, its logic at least intuitively intrinsic to any decision involving sensible choice. However, it was not until passage of the Flood Act of 1936 that cost/benefit analysis became ordained as a necessary step in the decisionmaking process. The legislation specified that no major construction project would be authorized unless its benefits could be calculated to exceed its costs. Exquisitely simple as to language and logic, this requirement made a numbers game out of public management. And over forty years of application in water resource planning have failed to overcome such basic weaknesses as costs underestimated, with calculations limited to visible dollar amounts, opportunity costs omitted, spillovers overlooked, and a range of present and future costs ignored. Social and environmental costs, because incalculable, were not calculated. On the benefit side, computations were found to be overly optimistic, not adequately supported, and lacking in consistency [3]. Not only does the outcome of the calculations depend on who is the Paul getting robbed and the Peter getting paid, but the "hard" numbers produced to justify huge projects have failed to pass the test of time. *Ad hoc* justifications for large water projects turned out to be *post hoc* fiascoes.

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[2] Ida R. Hoos, *Systems Analysis in Public Policy*, Berkeley, California, University of California Press, 1974.

Moreover, for all "scientific" pretensions, the management of water resources remains largely a political matter. Anyone who has followed the course of the current proposals by the Administration to cancel a number of projects will recognize how economics, politics, and environment all impinge on the decisions being made. Governor Richard D. Lamm of Colorado made an eloquent statement on this very matter. He said, "No public decision can be, or should be, made solely on the basis of dollar costs versus dollar benefits. The full range of economic, social, and environmental consequences, many of which cannot be measured in dollars, must be considered. If the cost/benefit ratio were the sole test for use of public funds or resources, would we have wilderness areas, wild and scenic rivers ... or the Washington, D.C. Metro?" [4]

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[3] U.S. General Accounting Office, Report to the Congress by the Comptroller General of the United States, Improvements Needed in Making Benefit-Cost Analysis for Federal Water Resources Projects, Washington, D.C., B-167 941, September 20, 1974, p. i.

Despite the years of experience that corroborate the contention that cost/benefit analysis is a teeter-totter game that all can play, it remains the key guideline for public decisionmaking, the concept having derived new vitality from its reattribution during World War II in the context of weapons systematization and selection as McNamara's "biggest bang for the buck". Patently detrimental in public program planning in general, cost/benefit analysis is positively disastrous as a measure of new technologies. It appears to be a double-edged sword of Damocles as it hangs over the head of remote sensing. In the guise of "technology assessment", it has imposed a necessity for premature evaluation, which has forced a kind of polarization. At the one extreme, there is the quantification of pie-in-the-sky, the placing of dollar values on benefits not realized and perhaps of a nature and in a time frame elusive of this method of calculation. On the other hand, there is the "bean counting" that is associated with management of resource agencies and that dictates that the use of remote-sensing data must contribute in an immediately visible cost-effective way to the operation of the given agency. Short-term objectives not only saddle the new technology with an onus beyond its proper limits of responsibility, but also contribute to a kind of peaches-and-pears mishmash made up of spurious and ill-founded comparisons.

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[4] Richard D. Lamm, "Our West, Water and Carter", The New York Times, June 19, 1978.

Perhaps I am asking too much of my academic colleagues. Perhaps they have found the cost/benefit exercise irresistible as a Ph.D. topic in that it entails a relatively low order of thought and readily produces the requisite number of charts and tables. But I should warn them of the boomerang. Today's students are tomorrow's policy makers and resource managers. If we teach them to function as knee jerks, responding in reflex fashion to limited stimuli, we cannot expect imaginative leadership from them. Education, in my book, is a mind-stretching process. You, as educators standing on the threshold of a Space Age whose wonders are just beyond the reach of our minds, have a unique challenge and opportunity -- to participate in the process of technology transfer so that the view from space will be utilized to serve mankind beneficially.

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THE ATTRIBUTES OF A WELL-TRAINED REMOTE SENSING TECHNOLOGIST

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Introduction

Having been asked to prepare a paper on the attributes of a well trained remote sensing technologist, there is a great temptation, I must admit, to describe the renaissance man, a "man for all seasons," who is all things to all people. The reason behind this temptation is the basic realization of the breadth of physical, biological, and socioeconomic information embodied in or better, which can be gained through appropriate application of manual, automated and/or for want of better terminology, machine assisted remote sensing data analysis techniques today. One has only to examine The Manual of Remote Sensing (Reeves, 1975), a work of over two thousand pages by some 350 authors, and then realize how far we have come since this material was put together to see some of the problems. Basically, how much breadth and to what depth should the remote sensing technologist be trained in his chosen field? Even more critical for educators, how can we identify those individuals with potential in an early stage of their academic career?

These were some of my thoughts in putting together this paper. However, in preparation for this conference, in an attempt to structure the invited papers, Robin Welch provided each selected author with a number of questions related to the theme he/she was asked to expand upon. My questions went like this:

III. Attributes of a Well Trained Remote Sensing Technologist (60 minutes)

A. What are the factors an employer looks for in evaluating a candidate for employment, whether as a teacher, data collector, data analyst or processor or graphic technician?

B. What are the basic skills, their priority and relative importance for various job descriptions and what are some of the specialization now being requested by employers? What are the weaknesses noted by employers?

C. What type of work or research experience in both academic training and "apprenticeship" is desirable?

D. What type of individual, his goals and personality (from the standpoint of motivation) should be recruited for training to be a remote sensing technologist?

E. What are some of the basic approaches available to faculty members to recruit and train these individuals?

F. Should we take discipline-oriented students and train them in remote sensing or remote sensing specialists and train them in a necessary discipline?

G. There is a difference between a technician and a technologist. How should academia meet the needs of both?

Each of these questions commands an answer which could be a full paper in its own right. A number have significant basic philosophical points embedded in them which have been and are being argued to this day (e.g. are universities mainly training students to go out and get jobs, or should we be principally concerned with training students to think, though frankly, I believe the two not as mutually exclusive as many of my colleagues appear to). Suffice to say that I will not even attempt to definitively answer all these questions. Indeed, my presentation will raise some questions which are not among those listed above. My goal in this paper is to briefly, and not necessarily in the order listed above, provide my perspective on the questions asked as a mechanism for stimulating discussions on what I consider very important concepts central to remote sensing education.

I will begin with a discussion of what employers are or appear to be looking for at this time in a prospective employee in the area of remote sensing, and follow this with a brief discussion of some of the ways in which faculty can get students interested in remote sensing. I will then proceed to a discussion of some of the attributes of a prime candidate with some thoughts on what the goal of his/her education can or should be; concluding with, again, my perspective on the current status of remote sensing education in colleges and universities.

What are employers looking for?

This section of the paper provides a response to the basic questions: what are the factors an employer looks for in evaluating a candidate for employment, whether as a teacher, data collector, analyst, processor, or graphic technician; and what are the basic skills, their priority and relative importance for various job descriptions; and what are some of the areas of specialization now being requested by employers and what weaknesses are rated by employers.

The reader will readily appreciate the all encompassing nature of these questions and the difficulty of presenting within this limited discussion, detailed answers. However, in order to formulate an adequate response to these questions, a telephone survey of about thirty individuals was conducted. These individuals represented a cross section of academic, governmental and private industry. All were potential employers of individuals with training in remote sensing. What emerged from this survey was the expression of a nearly unanimous preference for strong discipline or applications oriented background with some training in remote sensing; as opposed to a person specifically trained to be a remote sensing specialist. In, addition, many respondents expressed the desire for the prospective employee to have achieved an understanding of the basic geometry of the aerial perspective. Finally, in general, all those surveyed expressed the desire for that attribute which I believe every employer looks for: a high degree of motivation - that is, a genuine interest in the task at hand.

Within industry today, few companies which focus on remote sensing offer what might traditionally be described as specialist positions. Most individuals from companies in the private sector contacted expressed their preference for hiring discipline oriented specialists who have acquired basic skills in remote sensing. This with the notable exception of those firms employing photogrammetrists or photogrammetric technicians. Most firms also express a strong preference toward training in the use of aerial photography although several stated that this is beginning to change; and the rate of this change appears to be accelerating. Industry is a large buyer of digital data from the EROS data center in Sioux Falls, South Dakota, and power and mineral companies are buying thermal infrared and active microwave data. As the use of these types of data continues to grow and more sophisticated techniques for extracting relevant information are developed and begin to be employed, I believe we will continue to see changes occurring in the criterion upon which employees are evaluated to more of a balance between discipline and technique specialisms and conventional photo interpretation to more sophisticated multisensor/automated image analysis backgrounds. Indeed, in the future we may see the two separate as companies begin to focus on a team approach to addressing discipline oriented problems with a combination of individuals with various skills and backgrounds. In some companies this has already begun to occur, however, the level and ultimate value of the contribution of a true remote sensing specialist has not been fully developed let alone evaluated within this context to my knowledge as yet.

Agencies of the federal government employ a large percentage of what could be termed remote sensing specialists. Many of these individuals are recruited after receiving college training in any of a number of earth science oriented disciplines or having had some military training for jobs as image intelligence analysts. Federal agencies, with the possible exception of those employing the type of analysts pursuing either research or applications in remote sensing, such as the National Aeronautics and Space Administration are strongly oriented to again employing discipline specialists with remote sensing as a highly desirable, attractive skill. These agencies are examining ways remote sensing can help them fulfill their mandated responsibilities. As such they often have few avenues open to them for testing the value of new techniques and methodologies even when the knowledge of their potential reaches key decision makers. Based on my perspective I see the current situation with respect to government employment of individuals with remote sensing backgrounds continuing in the current mode for the forseeable future. That is, an emphasis on employing individuals with discipline oriented training who have acquired some facility with remote sensing techniques and methodologies.

In education there are basically two overlapping levels of employment for individuals with a remote sensing background: teaching and research. Most individuals who teach remote sensing courses have a discipline focus, e.g., geology, forestry, geography, engineering, etc. This is in a large part due to the evolution of remote sensing courses within these traditional academic departments. It has only been in the last few years that individuals at a number of institutions have begun to recognize remote sensing as a specialty worth of degree emphasis. As yet to my knowledge, there are no Departments of Remote Sensing, however, as will be discussed in more detail in the conclusion of this paper, this prospect may not be as far fetched as many of us currently believe.

Another area of employment for individuals with remote sensing skills in academia is in funded research. A good deal of the workload in funded research in remote sensing in academic institutions is carried out by either professional, graduate, or undergraduate researchers who are employed in nonteaching positions. These individuals often but not always have the discipline orientation of the departments wherein their research appointments reside. Indeed, in my opinion, some of the best research organizations within academia are those which employ individuals with a mix of backgrounds in a team research fashion. The criterion of individual members recruitment varies, but what is often looked for is a particular match of discipline or technique-oriented skills which have particular reference to a research task at hand. Again, academic discipline or traditional technique oriented skills are important but so too is a facility in remote sensing.

What are educators looking for?

This section deals with questions concerning the types of individuals, their goals and personalities which may make them good candidates for training in remote sensing; and how faculty members recruit and train them. These are the questions put to me. It is difficult for me to provide guidance in this area. Other than basic "God, mother and apple pie" statements concerning the roles and philosophy of education as applied to remote sensing such as:

- Give the student his true intellectual moneys' worth;
- Teach well structured classes and provide meaningful laboratory exercises;
- Convey a sense of enthusiasm for the subject matter;
- Let the student know that in remote sensing both the basic and applied research frontier is very close to the classroom; and
- That remote sensing offers a powerful tool to upgrade their understanding of many courses in the natural and environmental sciences.

If an instructor is successful in truly accomplishing all the objectives stated above, word concerning his/her class will get around and the first step in determining who the prime candidates are will be accomplished ("First you have to get them in the door"). Yet, how does an instructor know when he is truly accomplishing the above? Accurate precise methods of evaluating instructor performance is the holy grail of education; much sought but never attained. My answer is that you can never be sure and must continually strive to improve and to do your best within the limitations of the system within which we all operate; committee meetings, administration and all. One certain indication is class size. Here, by the reports I have received from many of you attending this conference, either we or our subject (I prefer to believe it's both) must be doing something right. At a number of institutions, demand for basic courses is outstripping departmental resources needed to effectively handle them. We must be careful here that a desire on the part of some department heads and administrators for "body counts" does not lead us to compromise on the basic requirements of our students. Remote sensing courses demand a high degree of active faculty student contact. If classes are large enough, teaching assistant support should be provided so that students can have the opportunity to effectively interact with individuals who are well trained and can efficiently help lead them up the learning curve.

I have been asked about the type of individual who would make a well trained remote sensing technologist? Again some general statements could be made concerning the individual possessing an appropriate mix of physical and mental characteristics in terms of: visual acuity or the ability to distinguish tone or brightness levels; ability to perceive parallax; a capability to distinguish color and fineness of detail and who displays a resistance to visual fatigue. Along with these attributes goes mental acuity in terms of: patience; judgement; the ability to work accurately; and, a quick problem-solving oriented mind. On top of these, my prime candidate would have to have some mix of: initiative; perserverance; resourcefulness; enterprise; curiosity; ingenuity and motivation. I am sure many of you could add to these lists, but we should all be aware of the plain truth: a prime attribute of the true candidate is that he/she wants to be a remote sensing technologist. That he/she has the desire and takes the initiative to secure the position. The bottom line here as it were, is that the best remote sensing technologists tend to select themselves. We may give them the opportunity and help them along, but we as educators cannot do it for them. Unless they possess the background experience and prepare themselves to take advantage of an opportunity to demonstrate their potential there is a limit to what we as educators can do.

It is however, important here that we as educators to some extent reflect back on what I have discussed earlier as we look at what attributes employers look for in our students. As such, we should attempt to make our students aware of these desires and to some extent, as many if not most of us already have, to structure our curricula to provide our candidate remote sensors with:

- Strong backgrounds in a specific discipline or application areas.
- Solid basic training in aerial photographic interpretation; and insure that they are fully capable of extracting information from all types of imagery both analog and digital.
- That they have the opportunity to have some form of hands on computer image processing experience with Landsat data, and not be shy at all of operating with computer systems.
- And that they receive a broad exposure to many types of remote sensing data (TIR, microwave, etc.).

In addition these individuals should get an appropriate amount of experience in the following areas:

- Project planning
- The role of field work, including specific techniques and methodologies of ground-truth data collection
- Physics of electromagnetic energy
- Systems design
- Statistical techniques
- Cartography and,
- Information systems

Finally, one thing we may also all agree on is that there is no substitute for hands on experience. I believe that hands on experience is essential in the training of a remote sensing technologist. Most remote sensing educators I know would agree that as much if not more education can go on outside the classroom as within. That apprenticeships, internships, research assistantships or even teaching assistantships are important and extremely popular methods of furthering a prime candidates' education in remote sensing. This basic, applied or pedagogic experience can serve to fill the gap between academic and fully applied remote sensing work. It is my feeling that just as we improve our interpretation capability by interpreting as many images as often as possible, exposure to a wide range of experiences is an excellent attribute in the background of the well trained remote sensing technologist. The critical question which I have not answered and which is beyond my ability to answer here, is who of us is truely capable and competent to provide this full range of opportunities to those students who truely desire to become well trained remote sensing technologists. This leads me to my concluding remarks.

Conclusion

We are faced today with an explosion of knowledge in all fields. This increase in information relative to many disciplines is creating problems within curricula at many institutions. How do we provide our students with a basic "general education" while still preparing them with sufficient background in a particular area to function efficiently if employed in that area. This is certainly true if not more so if we examine the conflict this creates for remote sensing.

Basically, we have a proliferation of knowledge concerning basic physical concepts, systems, interpretive techniques, and applications. The growing knowledge is creating problems. The question arises: how does an instructor adequately cover such topics as:

- Basic interpretation and measurement techniques
- The physics of electromagnetic energy
- Recording and analysis of data for advanced sensor systems
- The range of applications potential of sensor systems
- Future sensor and analysis systems and capabilities

in one, two, or even three courses. What of the students' need for a background in physics, image processing, statistics, cartography, and so on. All of this leads to the basic dichotomy remote sensing in colleges and universities throughout the country are already or, I believe, will shortly be finding themselves; that is:

- Remote sensing is rapidly approaching a state of technology and a body of coherent knowledge and theory to be viewed as a discipline in and of itself; yet,
- Nearly all of those individuals when asked what type of background they would look for in the hiring of a remote sensor said they would like a person with a strong applications oriented or disciplinary background with some training in remote sensing.

As a geographer, let me elaborate on this topic by providing some background on the similarities between the status of remote sensing and cartographic education. Cartography and remote sensing in American colleges and universities both find their principal pedagogic home in geography, especially in the case of cartography. Both fields share with geography a central concern with developing an understanding of the significance of spatial patterns on the earth's surface. Courses in cartography and remote sensing in geography are offered principally in departments large enough to offer at least an undergraduate major in the field. Such courses serve as a broad introduction to the fields and usually entail a mix of theory and practice appropriate for their liberal arts base of operations. Both remote sensing and cartography are regarded rightly or wrongly as tool or technique subjects and their continued presence in the curriculum is testimony of their perceived utility. In the past few years, courses and programs in these fields in geography departments around the country have increased, especially so in the case of remote sensing (Estes and Thaman, 1974; and Estes, Jensen and Simonett, 1977).

A number of differences between cartography and remote sensing are notable. Cartography is a field ancient in ancestry and very broad in its scope. Remote sensing is obviously a youthful field. Yet, in many ways it it equally as abstract and approaching the breadth of scope of cartography. Cognitive identity has been achieved recently for cartography and there are beginning to be indications that remote sensing is moving rapidly towards separate identity as a discipline as well (Dahlberg and Estes, in press). If we accept this premise that remote sensing appears to be rapidly approaching a state of technological diversity, having a coherent body of knowledge and theory sufficient to demand a separate curriculum and to be considered a discipline in and of itself; then how can we as educators continue to reconcile this with the responses of potential employers when asked what types of skills they look for in hiring, overwhelmingly state a preference for a person with a strong applications or disciplinary background with some training in remote sensing. How should we approach this dichotomy, the reconciliation of a perceived need for more education in a particular area with the preference of the job market for disciplinary skills coupled with technical facility? This is a matter then for active debate and indeed is part of the classic ongoing debate in education in this country. The central issue revolves around what the role of education should be. Should we be training students to assume their place in the job market with employable skills or should we be teaching people to "think?" Put in other terms, should we be training technicians or educating technologists (the term technologist is used here as being synonomous with professionals). While not admitting that these two thrusts either have to or should be different, let us examine and attempt to answer the question in the light of the reality of remote sensing education today. The Living Webster Encyclopedic Dictionary of the English Language defines "technician" as: one highly trained in the technicalities of a subject, profession, or occupation; one skilled in the technique of an art. "Technologists" is defined in the same source as a noun under "technology" which is defined as: the branch of knowledge that deals with the industrial arts and sciences; the utilization of such knowledge; the knowledge and means used to produce the material necessities of society. Training technicians then implies a vocational orientation, while educating technologists implies a more abstract or theoretical orientation. In essence, the dichotomy is akin to foresters training technicians to measure trees and educating technologists to manage forests. This would be similar to cartographers teaching technicians to draw maps and educating professionals (technologists) to convert spatial concepts into maps.

Remote sensing education at the college and university level in the United States today is basically technology-oriented. This may be in part a reflection of where such courses are taught; mostly in institutions offering advanced degrees where a possible combination of tradition, personal preferences, knowledge of the current market for students, and perhaps peer pressure have combined to produce the current situation. In essence, true vocational education in remote sensing is virtually nonexistent at the college and university level in the United States. What does this situation hold for the future of the well trained remote sensing technologist? Only time will tell. I will close on a positive note, however, and hope I will be forgiven for again going back to call on references to my discipline-geography.

There is and will likely continue to be a good job market for students with a strong disciplinary orientation and a good background in remote sensing. There is a small but growing demand for trained remote sensing specialists. This demand should continue to expand, and remote sensing educators should be ready to meet the challange. H. V. B. Kline, Jr., writing on the prospects for air photo interpretation in American Geography Inventory and Prospect, quotes John E. Kesseli as saying, "Only in departments so sufficiently staffed to consider all parts of the geographic field can it be expected that air photography has found or may find its due consideration as a research field." Furthermore, the student "...is inclined to neglect field and laboratory courses which provide a training in the gathering and interpretation of information, hoping that his problem will take care of itself when the time for independent research arrives." (Kline, 1954). Hopefully, in geography, at any rate, this situation is changing.

Remote sensing is a reality within geography whose time has come. It is too powerful a tool to be ignored in terms of both its information potential and the logic implicit in the reasoning process employed to analyze the data. When applied with the traditional cornerstone of geography, i.e., cartography, in its new digital raiment, the two techniques can go far beyond being mere technologies. We predict they could change our perceptions, methods of data analysis, models, and our paradigms. This process has, to some extent, already begun. The impact upon applications on the physical/ environmental side of geography is being felt, but the full potential for cross fertilizing synergism can enrich not only both the basic and applied sides of geography, but all of science as well. But this will be realized only if a larger share of the economic and social scientists make more use of the technique. And only if academics aggressively seek the research funding required to demonstrate the magnitude of the promise held in remote sensing in these areas and train their students accordingly. It is my feeling that in this way we as educators in any discipline will truly produce well trained remote sensing technologists.

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A MULTIDISCIPLINARY APPROACH
TO REMOTE SENSING EDUCATION

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The problems that distinguish remote sensing education from the great majority of educational programs are related to its multidisciplinary nature. Most of us as students and teachers have chosen one particular subject as our specialty. In some cases we were genuinely attracted to it, and in other cases it was the least of a number of evils that confronted us as undergraduates. In the good old days of twenty or more years ago, science students who abhorred mathematics, for example, could choose a program of study in which they could entirely avoid any contact with the subject. Nowadays, such study programs are relatively uncommon and not frequently recommended. The main reason is that throughout science there has been a marked increase in the automated acquisition of data, and as a consequence, the amount of data produced. To make effective use of the increased data volume, the modern scientist has to be familiar with data handling and statistical analysis procedures, which involve the use of digital computers. Without a basic knowledge of mathematics and the ability to program a computer the young scientist can rarely survive successfully. The older, well-established scientist, particularly the teacher of traditional remote sensing methods, can survive with difficulty and this I should emphasize can create problems in providing a well-rounded education to present-day students.

Remote sensing, by the nature of its extraordinary breadth and its rapid evolution during the past decade, presents to the teacher and student a more formidable problem in this respect than do conventional university disciplines. To emphasize this point, let me refer to figure 1, which I call the Remote Sensing Cycle.* Here we see a ground area that may be examined from ground level or from aircraft and satellite altitudes. The data from the satellite sensor are commonly converted to a digital form and telemetered to earth. At the ground receiving station, these data are recorded on magnetic tape in a computer compatible format. The computer can be used to correct geometric and radiometric errors in the data, suppress spurious noise, enhance image contrast, correct for atmospheric effects, sharpen edge profiles, and ratio the images from different spectral bands. Processed image data can then be classified by the computer using supervised and/or unsupervised clustering techniques. At this stage the use of collateral data can improve the accuracy of the computer classification. Such collateral data may be in the form of topographic and land use maps or earlier images of the same ground area that give clues, based for example on crop cycle, regarding the crops planted in certain fields. The classified ground scene information may then be used for a number of different purposes. First, it may be used for fundamental and applied studies, as in the agricultural and earth sciences. Second, it can form the basis for a study of the improvement in the accuracy of the classification--a study that will need the cooperation of the sensor system engineer, the atmospheric physicist, and the image processing and information extraction specialist. Third, the data can be used in a predictive model of, for example, crop production, in conjunction with other data from weather satellites regarding

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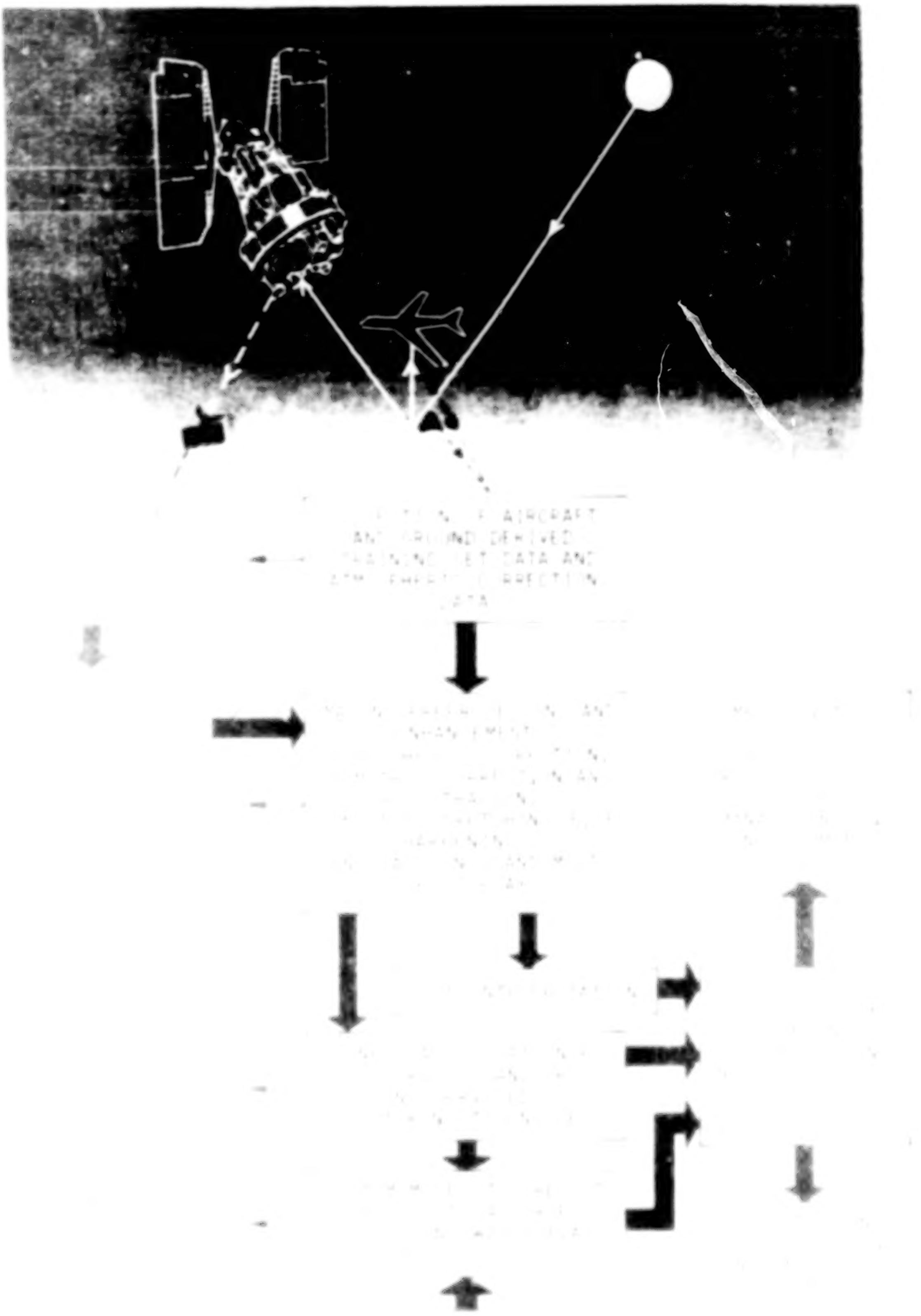
*From Remote Sensing: Optics and Optical Systems, by P. N. Slater, Addison-Wesley Publishing Company, Advanced Book Program, Reading, Mass.


COLLECTION OF AIRCRAFT
AND GROUND DERIVED
TRAINING SET DATA AND
ATMOSPHERIC CORRECTION
DATA
ENHANCEMENT

soil type and nutrient content, etc. Fourth, the data can be used in the study of such models in order to improve the model designs with respect to their accuracy and reliability.

Finally, the output from the model, or the information obtained directly from the data obtained by remote sensing, is then used by federal, state, and local planning and enforcement agencies for their particular purposes. It can also be used by private industry, for example, in the exploration for mineral and oil resources, and by international agencies for predicting regional food shortages, etc.

If this remote sensing cycle, from data collection to resource management decision, is to work effectively, there has to be a close understanding and communication between the various specialists involved. Systems engineers in optics, spacecraft, telemetry, data formating, image processing, scene classification, and modeling techniques are needed along with atmospheric and earth scientists of all types and the staffs of resource planning and enforcement agencies. Ideally, the resource manager should be fully familiar with the quality, and *particularly the shortcomings*, of the information he receives from a remote sensing system. He needs to be able to communicate at a high technical level with all the scientists and engineers who provide the various specialized steps in the remote sensing cycle. Similarly, it is important for the other specialists to have a broad understanding of all the steps in the cycle. It is through such an understanding that improvements in the overall system can be achieved.

Let me give two illustrations of the consequences of a lack of such understanding. The first illustration is a simple hypothetical example. A scientist working for the Food and Agriculture Organization (FAO) of the

United Nations determines he could distribute needed food supplies to a certain country in a timely manner if he knew of the impending failure of the main crop of that country a week earlier than current remote sensing techniques allowed. A university researcher has determined, from a carefully controlled experiment involving reflectance measurements in a laboratory spectrophotometer, that the onset of crop failure can be determined from a spectral reflectance change of 0.1%. The FAO scientist learns of this result and talks to image processing and scene classification experts and learns from them that they could provide this information if the sensor data had a signal-to-noise ratio sufficient to provide a noise equivalent reflectance difference (NE$\Delta\rho$) of 0.1%. Current sensors yield a NE$\Delta\rho$ of 0.4% so he requests that a system be designed to achieve this improved performance. The improvement over the current system is substantial: the optics have to be two F-stops faster and the image quantization has to be increased from 8 to 10 bits per pixel. The optical and telemetry modifications, including changes to the ground receiving stations, increase the cost of the system from $15 million to $30 million. The new system is put into orbit and operates to specification but does not provide the required information. Following a discussion with agricultural and atmospheric scientists the FAO scientist finds that, in his discussion with the image processing and scene classification experts, two critical factors were overlooked. One is atmospheric variability and the other natural scene variability. Both factors limit the reflectance difference that can be meaningfully extracted from the data. The moral of the story is that a $15 million mistake could have been avoided if any of those involved in the problem had a broader appreciation of remote sensing than that directly concerned with their specialty.

The second illustration is real and is provided by several articles that have appeared in the remote sensing literature in the past year in regard to temperature measurements. In reducing the data from surface radiance measurements taken with radiometers operating in one or more IR wavelength intervals, the authors have ignored two important facts. First, the well-known equation $M = \pi L = \sigma T^4$, relating radiant exitance, M, to surface radiance, L, and to absolute temperature T, where σ is the Stephan-Boltzmann constant, *applies only to perfect blackbodies which, by definition, are Lambertian emitters of unity emissivity*. Second, *the measurement has to be made over all wavelengths*. The first oversight concerns emissivity, and it is easy to show that an uncertainty in the knowledge of emissivity of 0.02 (from 0.9 to 0.92) constitutes 50% of the change in radiance of a surface due to a 1 K change in temperature. The second oversight, regarding the wavelength interval used, also has a substantial effect on the result. Depending on the position and width of the wavelength interval used, the exponent in the equation can be much higher than 4; for example, for a 300 K surface measured in the 1 to 2 μm wavelength interval the exponent is about 25. To totally ignore the emissivity problem and to use an exponent value of 4 regardless of the wavelength interval used shows an egregious deficiency in the education of the authors and an only too prevalent tendency to oversimplify the reduction of data collected by remote sensing systems. In fact, as a class, remote sensing measurements are among the most difficult of any in the physical sciences because of the large number of variables involved, many of the variables being unknown and some varying in unknown ways during the course of the measurement.

I hope, with the aid of these examples, that I have sufficiently emphasized the urgent need for a multidisciplinary approach to research and applications studies in remote sensing. Before proceeding to describe how we, at the University of Arizona, are attempting to educate students to be aware of both the methods and problems in remote sensing, I will describe some matters of general philosophy.

General Philosophy

Upon embarking on a campus-wide educational program in remote sensing, we had to answer several questions:

(1) Should the program be organized and monitored by an existing University department, a new department or center of remote sensing, or a University committee?

(2) Should the program be directed toward undergraduate or graduate students?

(3) If the program is directed toward graduate students, should it lead to a Ph.D. in remote sensing?

The answers to these questions depend on one's view of the role of remote sensing. The several of us who considered the questions, view remote sensing as *a means to several ends, not an end in itself*. Furthermore, for any remote sensing activity (education, research, or application study) to be conducted effectively, *it should be conducted in a multidisciplinary manner*. To run a broad-based campus activity from a single department or center is difficult because of the inevitable political problems that arise. To establish a new department or center is likely to prove more divisive than constructive, when an atmosphere of close cooperation is needed. In answer to the first question, then, it was decided that the educational program should be organized and monitored by a University Committee on Remote Sensing.

Because of the complexity and breadth of remote sensing, we agreed that the educational program should be directed toward graduate students. However, we also agreed on the desirability of an introductory course at the undergraduate level. We hope this introductory course will whet the student's appetite for more and guide him in the direction of remote sensing for his graduate program.

The answer to the third question, based on our opinion that remote sensing is not an end in itself, is that there should not be a Ph.D. degree awarded in remote sensing. (It would have required special approval from the Board of Regents for a committee, rather than a department, to award a Ph.D. degree. A request for approval would not have been consistent with the above philosophy and we may well then have sought department or center status.) We decided to petition the University administration and the Board of Regents to allow the Committee to award a minor in remote sensing as part of a program where the student's major was in an applications or techniques discipline. This petition was granted last year and the program is now established at the University.

University Committee on Remote Sensing

The University Committee on Remote Sensing comprises 13 members representing 10 campus units (eight departments, a center, and an office) and the departments in turn represent six colleges. Figure 2 is a diagram showing the participating campus units and Committee members.

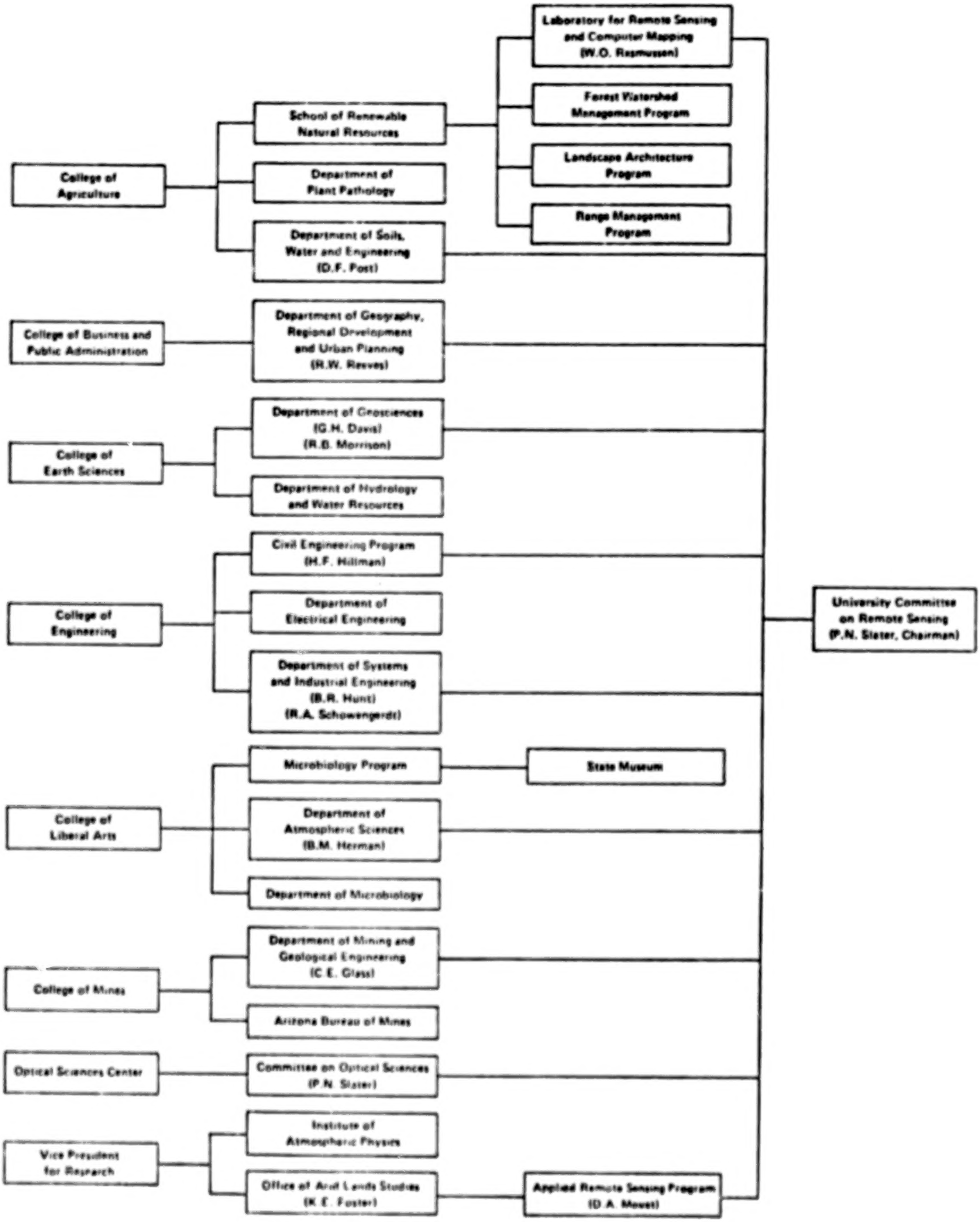

Laboratory for Remote Sensing and Computer Mapping (W.O. Rasmussen)
Forest Watershed Management Program
Landscape Architecture Program
Range Management Program
School of Renewable Natural Resources
College of Agriculture
Department of Plant Pathology
Department of Soils, Water and Engineering (D.F. Post)
College of Business and Public Administration
Department of Geography, Regional Development and Urban Planning (R.W. Reeves)
Department of Geosciences (G.H. Davis) (R.B. Morrison)
College of Earth Sciences
Department of Hydrology and Water Resources
Civil Engineering Program (H.F. Hillman)
College of Engineering
Department of Electrical Engineering
Department of Systems and Industrial Engineering (B.R. Hunt) (R.A. Schowengerdt)
University Committee on Remote Sensing (P.N. Slater, Chairman)
Microbiology Program
State Museum
College of Liberal Arts
Department of Atmospheric Sciences (B.M. Herman)
Department of Microbiology
Department of Mining and Geological Engineering (C.E. Glass)
College of Mines
Arizona Bureau of Mines
Optical Sciences Center
Committee on Optical Sciences (P.N. Slater)
Institute of Atmospheric Physics
Vice President for Research
Office of Arid Lands Studies (K.E. Foster)
Applied Remote Sensing Program (D.A. Mouat)

Figure 2. Participating Campus Units and Committee Members

Compared to many others, the University of Arizona is fortunate in having strong programs in remote sensing techniques. Four of the Committee members represent the techniques programs in Atmospheric Sciences, Optical Sciences, and Systems Engineering. The two campus remote sensing applications laboratories, that of the Applied Remote Sensing Program and the Laboratory for Remote Sensing and Computer Mapping, are represented on the Committee as shown in figure 2.

University Courses and the Graduate Minor in Remote Sensing

With the goal of suggesting courses for a graduate minor, the Committee on Remote Sensing, reviewed existing courses, modified some to reduce duplication, and added new courses. The courses are listed in Table I.

"Introduction to Remote Sensing" (D. A. Mouat) was added as an undergraduate course. In this course, the more important aspects of remote sensing are reviewed, the emphasis being on applications. The University has a large undergraduate enrollment in the applications disciplines, and the course is aimed mainly at them. (Atmospheric Sciences and Optical Sciences do not enroll students for undergraduate degrees.)

"Physics of Remote Sensing Measurement" (P. N. Slater) and "Image Processing Laboratory" (R. A. Schowengerdt) are new courses and are mandatory for the remote sensing minor. The first deals with the physics of remote sensing measurements, radiometric principles, spectroradiometric instruments, the interaction of electromagnetic radiation with the earth's surface and the atmosphere, and a description of how remote sensing systems work. The second course concentrates on the application of computer algorithms for image processing and classification purposes.

TABLE I - UNIVERSITY OF ARIZONA COURSES IN REMOTE SENSING

DEPARTMENT	COURSE TITLE	INSTRUCTOR
	UNDERGRADUATE	
INTERDISCIPLINARY	INTRODUCTION TO REMOTE SENSING	D.A. MOUAT
	MANDATORY FOR MINOR	
OPTICAL SCIENCES	PHYSICS OF REMOTE SENSING MEASUREMENTS	P.N. SLATER
SYSTEMS ENG.	IMAGE PROCESSING LABORATORY	R.A. SCHOWENGERDT
	TECHNIQUES EMPHASIS	
OPTICAL SCIENCES	IMAGE PROCESSING: DEVICES, SYSTEMS, APPLICATIONS	B.R. HUNT
OPTICAL SCIENCES	AUTOMATIC INFORMATION EXTRACTION, CLASSIFICATION	P.H. BARTELS
OPTICAL SCIENCES	RADIOMETRY	W.L. WOLFE
OPTICAL SCIENCES	INFRARED TECHNIQUES	W.L. WOLFE
OPTICAL SCIENCES	PHOTOGRAPHIC RECORDING PROCESSES	P.N. SLATER
OPTICAL SCIENCES	COHERENT OPTICAL DATA PROCESSING	J.D. GASKILL
OPTICAL SCIENCES	METHODS OF IMAGE RESTORATION AND ENHANCEMENT	B.R. FRIEDEN
OPTICAL SCIENCES	OPTICAL PROPERTIES OF THE ATMOSPHERE AND OCEAN	B.R. FRIEDEN
ATMOS. SCIENCES	ATMOSPHERIC OPTICS AND RADIATION	B.M. HERMAN
ATMOS. SCIENCES	RADAR METEOROLOGY	L.J. BATTAN
ATMOS. SCIENCES	PRINCIPLES OF ATMOSPHERIC REMOTE SENSING	B.M. HERMAN
ELECTRICAL ENG.	PROPAGATION OF RADIO WAVES	J.A. REAGAN
	APPLICATIONS EMPHASIS	
CIVIL ENG.	PHOTOGRAMMETRY	H.F. HILLMAN
WATERSHED MGT.	PHOTOGRAMMETRY	P.N. KNORR
WATERSHED MGT.	PHOTOINTERPRETATION	G.S. LEHMAN
AGRICULTURE	REMOTE SENSING IN AGRICULTURE	W.O. RASMUSSEN
GEOGRAPHY	GEOGRAPHIC APPLICATIONS OF REMOTE SENSING	D.A. MOUAT
GEOSCIENCES	APPLIED REMOTE SENSING	R.B. MORRISON
GEOLOGICAL ENG.	PHOTOGEOLOGY	C.E. GLASS
GEOLOGICAL ENG.	APPLIED MULTISPECTRAL IMAGERY	C.E. GLASS

Students are able to use an I^2S, three-color display coupled to a PDP-11/70 mini-computer in interactive experiments to evaluate for themselves the utility of the various algorithms available.

The 12 techniques courses listed in Table I are not directed specifically toward earth resources remote sensing studies. However, three of the eight applications courses with "remote sensing" in their titles are exclusively concerned with remote sensing, as is the course entitled, "Applied Multispectral Imagery."

A student can choose an emphasis in either applications or techniques for his minor, provided he takes the two mandatory courses and his program receives Committee approval. We hope that students who receive the remote sensing minor with an applications emphasis will pursue a program in their major that involves making their own remote sensing measurements or using remote sensing data collected by satellite or aircraft borne sensors.

Facilities

In my opinion, an obvious and vital need in teaching remote sensing is a good set of slides and the availability of suitable projection equipment in the lecture room. Slides replace the inconvenient distribution of books or photographic prints during the lecture or the display of imagery to a crowd of students around a light-table after the lecture. Surprisingly, I know a number of university lecturers who would never think of giving a colloquium or seminar *without* slides and yet would never think of giving a lecture course *with* slides! In these days there are many sources of slides on remote sensing and there is no excuse for not using slides routinely in teaching remote sensing.

The other important aid in teaching modern remote sensing is a digital, color, interactive CRT display. Increasingly, the analysis of Landsat data is being conducted directly with computer-compatible tapes rather than from the photographic product. There are three reasons for this:

(1) Film does not cover the 64-step dynamic range of the present Landsat Multispectral Scanner (MSS) response and the MSS digital data recorded on magnetic tape. This will be an even more serious limitation with the 256-step digital data from the Thematic Mapper. For this reason, small reflectance differences, discriminated in the digital data, will be undiscernible in the photographic product over the full range of average reflectance levels encountered. Another consequence is that quantitative radiometric data are of poorer quality when recorded and extracted from a film record than from magnetic tape. Automated scene classification work can then be conducted more accurately with digital rather than photographic data as the input.

(2) The Thematic Mapper and other future systems will have pixel areas roughly 7 to 28 times smaller than the pixel area of the MSS. This will increase the usefulness of future satellite data and decrease the relatively high present importance of photographic remote sensing from aircraft.

(3) Image data in digital form can be manipulated to a much greater extent using an interactive CRT color display system than can multispectral photographs in an additive color viewer. Besides

being able to monitor efficiently the efficacy of image processing routines and to carry out visual interpretation of the displayed image, these systems can be used for the display of the results of scene classification procedures.

For these reasons we cannot continue to offer a set of remote sensing graduate courses that do not expose the student to the methodology and facilities he will encounter in his future professional career in remote sensing. The main problem that confronts a university in this regard is the high cost of the initial purchase of such equipment plus the cost of an equipment maintenance contract. Fortunately, in our case, the University made a substantial facility contribution to the remote sensing program, and this has been augmented by support from the Air Force Office of Scientific Research. With this important exception, all facilities at the University that are useful for remote sensing education were obtained for research and applications projects. *If there is one way in which NASA can contribute to an improvement in remote sensing education in this country, it is through capital equipment grants to universities that have personnel interested in and capable of exploiting image processing and scene classification procedures.*

Future Developments

Our remote sensing academic program at the University has evolved during the past few years by virtue of the interest and concern of the members of the Committee on Remote Sensing and the strong support of the University administration. Most of us hope the establishment of the program will stimulate the initiation of more multidisciplinary research and applications studies. Early in its discussions the Committee agreed that it was preferable to establish an academic program first, before trying to expand the remote sensing research activities. The reason is simply that the needs are mutual: University faculty and staff cannot and should not pursue substantial research activities without the involvement of graduate students and graduate students in turn benefit from a structured program which can also afford them financial assistance.

We have reached the stage at the University where the first students have completed their course work for the remote sensing minor. It will be of interest to see how many of them proceed with remote sensing projects for their major and to what extent the members of the Committee can work together to generate successful multidisciplinary proposals that will support these students in research and applications studies.

In my opinion, it is one thing to organize a multidisciplinary remote sensing *educational* program at a university and quite another to organize a fully multidisciplinary (that is, multidepartmental) research and applications program. At this point I feel the University of Arizona has succeeded in the former and I hope some of you may benefit from hearing of our approach and experience. I don't think we yet know whether we can mount a fully multidisciplinary research and applications program. I shall look forward to hearing from others at this conference how, and to what extent, they have been successful in this regard.

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REMOTE SENSING RESEARCH ACTIVITIES RELATED TO ACADEMIC INSTITUTIONS

Victor I. Myers

Remote Sensing Institute
South Dakota State University

Research as a Means to Advance the Frontiers of Technology

The principal responsibilities of those attending this Educator's Workshop are in teaching and research, some with greater responsibility in one area or the other, but all, I am sure, have an interest in both. My major activity is that of research, as you may surmise from my speaking assignment, but the organization that I represent is involved in education and training as well as research.

The word research is now applied to so many activities that even in a scientific research organization its use may be ambiguous. It is often used to describe aspects of professional scientific activity which might not normally be regarded as scientific research, and it may even be used to describe the resurrection of existing information in a new form.

For the purpose of defining research I prefer to consider the term without the usual adjectives of basic, applied, experimental, theoretical, and so forth. Research is the quest for new information. There are numerous types of investigations, but as far as universities are concerned it is important that the investigations are in the vanguard of knowledge in the staff members' respective fields of expertise.

Prior to about 1840 research people were obsessed with identification and classification of things and phenomena (Raney, USDA, ARS, 1968). This was our heritage from the Greeks. At that time research people suddenly realized that this was really not a very useful approach and the so-called scientific method of research was born. This consisted of developing a hypothesis and then proving or disproving it. The Greeks were concerned with intellectual things, but their purposes were ill-defined. When the Romans enslaved them, the Greeks were most useful as teachers of the Roman children.

To me, true research means the pursuit of knowledge with a goal in mind. It means not only wanting to know but doing something about it. Having a goal in research is unlike climbing a mountain where the goal is clear. In research there are innumerable mountains and the principal problem is to decide which mountain to climb first.

Perhaps our greatest challenge is that of defining our problems. Should that be so difficult? Perhaps so, when one considers the user. In discussing this matter of defining problems Darwin said:

> You would be surprised at the number of years it took me to see clearly what some of the problems were which had to be solved. Looking back I think it was more difficult to see what the problems were than to solve them, so far as I have succeeded in doing and this seems to me rather curious.

Research - For Technology or For Teaching?

I have accepted that definition of a university which includes the transmittal and the creation of knowledge. This, of course, affects the general objectives of research in the university system in that education must be a part of the overall objective.

In these times there are numerous constraints on the activities of research groups which are dictated by their objectives. But program objectives are most often dictated by local, state, federal and international organizations who have very specific requirements. The fact that these requirements are frequently motivated by today's needs in a world that is facing many ecological crises does, however, provide challenging opportunities in research and education.

Let there be no confusion about research direction, whether for technology or for teaching; rest assured that this is not a mutually exclusive affair. Undergraduate and graduate students can be handily worked into segments of contract or grant research studies and make a simultaneous contribution to the project and to their own education. Of course one must exert careful control over such activities by students, but what a stimulating challenge it is to a student to have an opportunity to work on a practical problem that needs a solution rather than on one from a textbook.

Our challenge today in science and technology as well as in education is that there exists a crisis of disillusionment with science and technology in the affluent societies of the west, Haskins (1973). The central question involved is one of national priorities. It comes with the realization that strong as we have always believed ourselves to be in talent and wealth, those resources are not infinite. We must make choices in what we elect to do with them.

What Kind of Organization

How a university can manage to preserve its detached role in education and at the same time engage in strict research and applications of technology is somewhat of a dilemma. One rather common approach to this is the departmentally based research and service program. Another approach which I personally prefer is that of the quasi-autonomous institute or laboratory such as our Remote Sensing Institute (RSI) at South Dakota State University. Other examples of this are The Purdue Laboratory for Applications of Remote Sensing and the University of Kansas Center for Research, and there are others.

The separate research institute, not a unit of the educational part of the institution but closely associated with it, can contribute to the educational program even though its supervision is no responsibility of the teaching faculty.

An example of the purpose and objectives of an organization with research, teaching and development activities might be as follows:

1. Identify regional, state, and local problems which remote sensing can help solve.
2. Assist users in applying remote sensing technology already developed.
3. Bridge the gap between the present-day application and state-of-the-art remote sensing capability.

4. Identify research needs to which remote sensing technology can be applied and conduct research programs to solve these needs as rapidly as funds can be made available.

5. Stimulate and cooperate with faculty and students in institutions in applicable areas of science and engineering.

6. Provide training through extended in-residence (6 months to 1 year) programs for individuals with previous resource training and experience.

7. Provide the organization with capability and expertise to assist local, state, and federal agencies in utilizing appropriate remote sensing technology in solving problems.

The ultimate responsible authority for the research organization deserves careful attention. In the case of RSI and other institutes or centers, the structure is such that the Director is responsible to a President or Vice President of the University. For RSI it was no accident that that particular form of structure was chosen. From the very earliest history of the organization it was emphasized that the normal University structure of having the Institute function under one of the Schools such as Engineering or Agriculture, or with multiple responsibilities to two or more Schools within the University was unsuited to the timely and efficient conduct of remote sensing scientific research.

Many necessary mandated procedures are in effect in the normal university structure, providing checks and balances. The field of remote sensing is rapidly changing sometimes requiring quick response to new requirements in programs or directions which must occur at a speed or in a manner not adapted to normal procedures of a university system. This is a necessary characteristic but requires wisdom and restraint in the decision making process to assure adherence to the objectives listed previously. The Second Law of Thermodynamics applies here which, stated in terms of human behavior, says it is easier to get into trouble than to get out of it.

In a resource-oriented organization it is essential to have interdisciplinary programs with emphasis on several resource application areas such as hydrology, agriculture, wildlife, geology and perhaps others. This requires association with a University system with personnel, equipment, and library services that are also resource oriented. A training program is also an interdisciplinary resource-oriented program requiring a similar association. Research that utilizes the expertise of several disciplines and focuses it on a particular problem area is relatively rare.

This does not mean, however, that any one organization need try to be excellent in all aspects of research, or to include in their curricula the full gamut of research fields and instructional offerings. Each group would do well to seek out its individual identity, clarify its specific goals, consolidate its strengths and terminate programs that cannot be justified.

A basic minimum level of support is essential for maintaining a broad multidisciplinary team in agriculture, hydrology, engineering, geology, wildlife, etc. Most resource problems involving remote sensing technology are multidisciplinary in nature. Should one have these staff members on full time or are there alternatives? Many institutions list numerous staff members from various departments as part of the remote sensing staff. Having scientists available from a wide variety of disciplines is of course one of the advantages of university research involvement. As you may well recognize, this situation also has drawbacks in that many of the faculty members who originally indicated an interest in participating in a research multi-disciplinary effort, if one came along, may not have the flexibility to do so when the need arises because of departmental commitments.

Another approach is to have available a group of consultants who are experts with broad experience in their fields. This approach may provide well-qualified people, but here again consultants may not have the desirable flexibility to fill the needs of a research program, particularly if lengthy service of a few months to a year or more is desired.

Suitable activities for a research and development group to become involved in are numerous. There is not always an organization waiting with open arms to fund every idea; however, many good projects wither away for the lack of vigorous promotion. As an example of the wide variety of possibilities Table 1 summarizes some past and present RSI research and development along with the involvement of state and federal agencies and university departments in these activities. Part time students and/or graduate students have been involved in most of these activities.

Table 1. RESEARCH AND DEVELOPMENT ACTIVITIES

SDSU Remote Sensing Institute

Activity	State Agency, University Department Participation	Federal Agency Participation
Land Use Planning, Soil	State Planning Bureau, Dept. of Revenue, 6th Planning District, Black Hills Conservancy Subdistrict, Oahe Conservancy Subdistrict, Pennington County Comm., Meade County Comm., SDSU Plant Science Department	Soil Conservation Service, NASA, U.S. Bureau of Indian Affairs (USBIA), U.S. Bureau of Reclamation (USBR)
Hydrogeologic Mapping	SD School of Mines and Technology	U.S. Geological Survey (USGS)
Groundwater Mapping	State Geologist, Department of Natural Resources, Oahe Conservancy Subdistrict	U.S. Geological Survey
Reservoirs and Lakes, Biological Activity, Quality Parameters	SDSU Biology Department, State Geologist	Office of Water Resources & Tech. (OWRT), U.S. Fish and Wildlife Service (USF&W)
Reservoirs and Lakes, Surface Area Determination and Classification		USGS, USF&W
Wildlife Habitat		USF&W
Ducks, Census, Sex Ratioing		USF&W
Streamflow Blockage in James River	Oahe Conservancy Subdistrict	
High Water Tables		USBR - Denver
Wetland Vegetation Classification		USF&W
Saline Seeps	SDSU Water Resources Institute, Montana State University, North Dakota State University, New Mexico State University	OWRT, Old West Commission, NASA

Activity	State Agency, University Department Participation	Federal Agency Participation
Snow and Ice as Hydrologic Indicators		USGS
Water Requirements of Crops	SDSU Redfield Station, SDSU Plant Science Department	USGS
Soil Moisture		NASA, USGS
Crop Identification and Yield Prediction		USDA-Science and Education Adm.(SEA), NASA
Rangeland Condition	South Dakota State University (SDSU) Animal Husbandry Department	NASA, USBIA
Agricultural Pollution on James River	Health Department, Oahe Conservancy Subdistrict	Environmental Protection Agency
Deer Census	South Dakota Game, Fish and Parks Department	
Highway Damage Assessment, East of Watertown, East of Rapid City	South Dakota Department of Transportation South Dakota School of Mines and Technology	
Dutch Elm Disease Detection	Department of Agriculture, SDSU Plant Science	
Wheat Mosaic Detection	SDSU Extension Entomologist	
Sod Webworm Infestation	SDSU Extension Entomologist	NASA
Park and Recreation Planning	City of Sioux Falls, Bicentennial Commission, SDSU Geography Department	NASA
Pale Western Cutworm Detection		USDA-ARS
Corn Rootworm Detection	SDSU Entomology Department	USDA-ARS
Sugar Beet Spoilage		American Crystal Sugar Company

Activity	State Agency, University Department Participation	Federal Agency Participation
Flood Damage Assessment	Black Hills Conservancy Subdistrict, Civil Defense, 6th Planning District	USGS, NASA
Tornado Damage Assessment	Civil Defense	
Hail Damage Assessment	County Agents, Hail Insurance Adjusters and Research Association	
Root Length and Area Determination		USDA-ARS
Leaf Area Damage Assessment		USDA-ARS
Beef Loins Area Measurement	SDSU Animal Science Department	
National Water Plan		World Bank, Mexico
Influence of Aswan Dam on Agriculture of the Nile Delta		National Science Foundation, Egypt
Education · Training	SDSU	State Department, AID United Nations, Individual Countries
Operational Resource Management Models, Belle Fourche Watershed	State Planning Bureau, State Department of Natural Resources, State Department of Game, Fish & Parks	NASA
Land Use Planning, Soil Classification, and Tax Equalization Studies	Potter County, State Department of Revenue	NASA
Desertification		United Nations Environmental Program, State Department AID

Activity	State Agency, University Department Participation	Federal Agency Participation
Energy Loss Surveys		Energy Research and Development Adm.
Resource Survey in the Sudd Region of Southern Sudan		Governments of Sudan and Egypt
Heat Capacity Mapping Mission	SDSU Engineering Physics	NASA

Curriculum Development to Integrate Teaching and Research

There are tremendous pressures on government agencies and universities to solve current problems, and no one denies that these problems are urgent. Despite these pressures which must be satisfied, the university by its very nature must be future-oriented because faculty and students together must provide knowledge, skills and leadership for much of the next generation. Potter (1970) believes that a future-oriented university would find ways for students and faculty to engage in interdisciplinary efforts that would achieve these objectives.

A student in science or engineering should possess above average ability in one or more of several directions:

a. An ability to grasp scientific principles

b. An ability to organize and carry out experimental investigations

c. A curious mind

Thus, any curriculum should introduce all students to courses that encompass all of the above, and make it possible for each of them to cultivate that ability which is dominant in him.

A curriculum should be diversified and this is where the knowledge, experience and training of the professor is important. A professor who is in touch with the real world, conducting research, and being alert to new developments can be a great asset to career preparation and development.

It is often said that an academic education should teach students to think. Kestin (1963) states that "... if he doubts his ability to teach a student, he certainly doesn't know how to teach him to think, or to synthesize, or to show a willingness to assume responsibility, or to exercise leadership".

Although, as Kestin points out, ultimately each student must learn for himself, one must not draw the conclusion that the organization of courses is unimportant. On the contrary, particularly in the early stages of the curriculum, the part played by the instructor is decisive. An ability to organize a course and to fire the imagination of young people so that they become personally and emotionally involved in learning requires a very special talent. It is suggested by educators that a program of study for students will fail unless the staff has ample opportunity to prepare their courses and to continue their own education. Thus, an educational program for students must also include an educational program for instructors.

The academic institution should recognize that in engineering and in the physical sciences it is necessary for the faculty to participate in research activities, not only for their own benefit but to maintain intellectual standards for the institution and for purposes of graduate instruction. Otherwise the teaching faculty tends to teach the ancient history of science and engineering instead of providing students with a foundation for making contributions in his chosen field for the next several decades. This is especially true of remote sensing technology which is dynamic in the sense that new technology is continually being synthesized.

It is undoubtedly true that promotion regulation by the administration very much influences staff activities. The promise of recommending or withholding promotion should not be used as a carrot stick, however, faculty should know that excellence will be rewarded, and that mediocrity will not.

It has been said many times that research makes a good teacher; this statement is doubtful. J.D. Ryder of Michigan State University (unpublished remarks) expresses a similar view in stating that research capability is a good, early indication of a man's ability as a teacher. He feels that at the age of 30 a scientist can be encouraged to continue in teaching or research or be diverted to other activity depending on his exhibited interest in research and his desire to gain knowledge. Ryder feels that the traits exhibited at age 30 are those that will still be identified with the individual at age 50. To summarize, research does not necessarily make a good teacher, but research is an indicator of the type of mind and type of ability which will make a good teacher. Conversely, a good researcher is not necessarily a good teacher.

Training of visiting scientists from many countries is a means for expanding the horizons of faculty and students. Financial support that comes with training programs provides funds for developing training documents and training aids, for purchasing training equipment, etc. Visiting scientists generally bring new knowledge and new problems which challenge faculty and students who may work with them. Training programs provide financial support for bringing specialists from government, industry and other universities to enrich the staff and other faculty and students.

Most especially, however, work with visiting scientists from other countries allows an interaction between specialists with similar problems in discussing, investigating, and suggesting methods to find answers to these problems, often with new approaches surfacing after a merging of ideas. Often our creative abilities are stymied and our ideas crystallized by the thoughts of a few "authorities" among our literature acquaintances or immediate associates. As we work with trained scientists with varied experience from other countries, free exchange of ideas is often more easily accomplished.

Training and Selecting Students for Research Activities

We are all interested in having some innate ability to spot bright potential researchers from among students. Potential employers in government and industry are interested in taking steps very early in a college student's career to place him in a training position and then hiring him upon graduation if a mutual attraction blooms between the individual and the employer. This plan just does not hold water in light of the experience of experts in this field. According to Dr. D.T.C. Gillespie of CSIRO, the Australian Government Research Organization, "It is common experience that the intellectual ability to absorb knowledge and the intellectual capacity for creativity do not necessarily go hand in hand. Thus, it is not unknown that a student with a high absorptive capacity, and even exceptional ability to reproduce with facility the material learned, may never become creative". This suggests that selection for creative ability cannot begin until quite late in university training. The best bet for selecting and/or recommending students for graduate studies or for employment would seem to be the one of watching for promising young seniors and graduate students.

Funding Sources

Based on present evidence, it appears that future research will become more complicated, more costly, and will require more team effort. With priority decisions to be made concerning expenditure of available funds, these matters are a principal concern of academic institutions. The 1950's and 1960's were decades of unprecedented financial support for science. Impressed by the contributions of science and technology to the war effort, Congress appropriated ever increasing amounts for research and development and, later for science education (Bevan, 1971). But late in that period the balloon burst or, perhaps more accurately, sprang a slow leak that has accelerated during the 1970's.

Throughout the earlier years of adequate funding, we in the scientific community assumed that if funds were made available to competent investigators, and if each did his own thing, then automatically the greatest good would accrue to all and the national interest would be served. This, perhaps, was a naive attitude and in the eyes of the taxpayer is no longer justified.

Another situation which many of you may recognize is that as research funds have diminished many federal agencies have turned more and more to internal research to support personnel already on payrolls and maintain government programs at least at the same levels as in the past.

The wheels of research and development -- either basic or applied -- cannot turn without the funds to oil them. The American public, now mainly urban, is generally apathetic to research. As long as he experiences no personal shortage of food and fiber, we can expect the voter to remain indifferent. A distinguished visiting scientist, Dr. Salah El Rabaa, Professor of Geology in the University of Khartoum, Sudan blames this on our entertainment-oriented rather than education-oriented mass media. According to El Rabaa "Believe it or not, the program which is most informative and educational is not received here in the U.S. - The Voice of America. It directs cultural, scientific and political information and current events in an interesting way to many countries in the outside world." He believes the Voice of America should be heard in America.

The changing pattern in the federal funding of science is an entirely new experience for a major part of the scientific fraternity. It is going to force the scientific world to redefine its goals and devise effective ways to help the Congress develop more rational long-range programs of support. According to present trends the physical sciences and engineering will find difficulty in the next 10 to 15 years in meeting needs for qualified teachers and well-trained research workers. Private and public funds that might support research as a part of the educational system will be inadequate due to demands for facilities and faculty salaries. It is therefore clear that institutes and departments involved in remote sensing research will be required to find other sources of funds to supplement appropriated monies.

Support for research must come from outside sources in the form of research contracts and grants from the federal government, international organizations such as the United Nations and World Bank, and from foreign countries.

The states have much to benefit by the direct support of research activities in universities. Substantial state appropriations are made toward the research activities in agriculture, and engineering. But so far there is little in the form of appropriations for remote sensing technology. Research activities provide a reservoir of ideas and of technical strength within the state from which the whole community benefits. Therefore, the states have a direct stake in the support of research at universities.

Private industry, the ultimate user of much of remote sensing technology, needs to become more involved in active planning and support of research and teaching activities. Remote sensing geologists receive this kind of support from oil and gas industry for reasons of organization and wealth. Most other disciplines such as agriculture, hydrology, wildlife, etc., are fragmented with individuals who alone cannot support research. These other disciplines also are provided many "free" services by government organizations and expect government to subsidize the research. Nevertheless, private industry could do a better job of providing input concerning user needs.

Finally the Federal Government cannot avoid a major responsibility in the support of research in universities. This is essential not only for the health of the research activity of the nation but more particularly it creates a close sense of intellectual participation between federal agencies and universities.

For a variety of reasons, the most desirable form of support should originate from a diversity of sources. There is a need for indepth research as well as applied research and development activities. It is wise to plan a program with a balance between research and applications. We all feel pressures and are responding to the need for demonstrated practical applications.

Some of the advantages of a diversity of contracts and grants are:

1 They provide income that helps give financial stability to a research organization which may be at the mercy of fluctuations that are inherent with dependence on contracts and grants.

2 They provide funding for a variety of resource applications

3 A minimum basic level of funding is needed for support programs such as the photo lab, the data handling group, and the data collection program, which might include aircraft.

Let me remind you of a great advantage that we have in funding remote sensing, that is our critical dependence on very costly scientific tools - the earth satellites. The instrumentation, launching, tracking, and data collection involved in the satellite program is very expensive, involving tens of millions of dollars.

Although funding for research is difficult to come by, this source of data is incredibly cheap and useful to the student, researcher, and user. The potential for developing new and dramatic earth applications captures the imagination of many students who wish to become scientists and engineers. The promise of major advances from the Earth satellite data in our understanding of just hydrology would in itself seem to justify an enormous effort in support of this equipment.

Developing Funding Sources

"We have met the enemy and they is us" - Pogo. These wise words of a modern American philosopher identify what I consider to be the critical element in the effort to sell research proposals.

We are faced these days with decisions concerning research ideas - sometimes it seems that the best ideas have already been thought of or that funding agencies are not smart enough to buy our brilliant ideas. Although selling research proposals sometimes seems equivalent to groping ones way through a maze, it remains a fact that funding agencies are most frequently not presented with good proposals. Shortcomings may be one of the following:

a. An old idea that is being resurrected

b. A poorly written proposal

c. An investigator who is not familiar with agency objectives

d. Not a good idea

On the other hand the path from the spark of an idea to a funded proposal is long, tortuous and full of pitfalls. Persistence plus good salesmanship are necessary ingredients in selling proposals.

Many, many good proposals wither and die because a researcher gives up after his first or second experience of receiving a rejection.

Making Science Effective

Although the responsibility of a university may include transmittal and the creation of knowledge, an institution supported by public funds must also meet its obligation to the community. These university objectives are important to graduate instruction as well as improving our standard of living. In our case at RSI, part of our obligations to the community are met by providing the following services to state agencies.

1. Provide leadership for cooperative programs - Example, Landsat follow-on program in a multidisciplinary watershed project involving three state agencies.
2. Gain federal support for projects to finance pilot or model studies as well as resource applications studies.
3. Provide education and training.
4. Provide personnel and facilities for conducting specific research and development programs desired by many state agencies.

Scientists working in the Earth Resources Applications program with government agencies have long recognized and been concerned about the "USER GAP", i.e., the lack of effective communication between the scientific community engaged in remote sensing research and development and the potential users of modern remote sensing technology. The lag between present-day applications and the state-of-the-art remote sensing capability is too great. Closing this gap will help insure reasonable payoff from the use of space, high altitude, and other remote sensing capability.

Despite recent technological advances we are yet unable to transform new ideas into successful products more quickly, according to a study by the Battelle Columbus Laboratories as reported in Parade Magazine.

Stressed throughout this report, which examined 10 innovations for the National Science Foundation, was the importance of what was termed the "technical entrepreneur" who persists in the face of various inhibiting effects.

The following provides an idea of the "USER GAP" time-frame as calculated for various innovations, including several which relate directly to agricultural research:

Innovation	Conception	Year of First Realization	Duration, years
Heart Pacemaker	1928	1960	32
Hybrid Corn	1908	1933	25
Hybrid Small Grains	1937	1956	19
Green Revolution Wheat	1950	1966	16
Electrophotography	1937	1959	22
Input-Output Economic Analysis	1936	1964	28
Organophosphorus Insecticides	1934	1947	13
Oral Contraceptive	1951	1960	9
Magnetic Ferrites	1933	1955	22
Video Tape Recorder	1950	1956	6
Average Duration			19.2

Despite the relatively long period of development required for the first realization of most technological advances, that period has been shortened remarkably for remote sensing technology, particularly as it refers to use of Landsat imagery.

Currently operational remote sensing applications are limited in number and other applications, though numerous, are often difficult and complex, requiring intensive research and development before they can be applied on a routine basis. Even proven applications that have yielded to research require development and demonstration to make them routinely useful. There has always been a considerable time gap between the completion of research and the stage of practical useage unless an extensive concerted effort is made to close the gap.

As we evaluate the areas of our investigations that pertain to the usefulness of research efforts we must keep in mind the specific needs of users. In that regard success depends on a rare blend of far vision and near vision - so stated by an editor of Forbes magazine. According to this editorial, the Greek philosopher Thales fell into a well while strolling along, gazing at the stars. It was his penchant for gazing at the heavens that made him great, but failure to keep his eyes on the ground killed him.

Participation and cooperation among federal and state agencies, industry and universities are some of the most progressive actions that can occur. An example of this is the soil moisture workshop jointly sponsored by NASA and USDA and organized by South Dakota State University. Many of you attended that workshop. Remote detection of soil moisture had long been an elusive goal. Research efforts as well as research goals have long been uncoordinated as they progress down narrow avenues with limited objectives using available research equipment rather than optimum equipment. The workshop was attended by over 100 scientists, engineers and administrators from government, universities and industry. The workshop recommendations should lead to a coordinated, adequately financed research and development program. NASA has held other workshops. Also, the U.S. Army Engineers recently held a hydrology workshop in Vicksburg, Mississippi, similar to the soil moisture workshop, but also involving other aspects of water. The workshop involved federal and state government and university specialists.

Bridging the Gap Between Research and Applications

An example of bridging the research-users gap is the work in South Dakota by Westin (1973), Frazee, et al. (1974), and others. In doing so they involved graduate students who used segments of the research projects for theses and thus were involved in useful studies.

The suitability of soils for various land uses in the more intensively utilized areas is routinely interpreted by soil scientists of the National Cooperative Soil Survey. In less populated areas the necessary soils maps are frequently not available or may be outdated. Early studies by Westin and Myers (1973), reported on the utility of Landsat images for identifying soil associations in western South Dakota. Landsat imagery then provided Frazee and associates, 1974, with a tool for making resource inventories in Pennington County in the same area. The resources consisted of soils, geologic material, and vegetation. Field checking consisted of a resource team of soils, geology, and range science specialists traversing the area. The final product was a series of base maps and overlays delineating the resource areas for an area of 400,000 hectares at a scale of 1:250,000.

The real payoff for this activity came about in developing a method for determining land values for tax assessment based on soil inventory data and land sales. Soil inventory data necessary to use this method are not available for over 40 of the 67 counties in South Dakota. General soils information must be used until detailed soil surveys are completed in those counties.

As a follow up to the development work for resource surveys in South Dakota we were instrumental in developing procedures for using remote sensing technology for assessing natural resources in several developing countries. In Mexico procedures were established in cooperation with Mexican scientists to assess 42.5 million hectares of land for potential development of better utilization of water resources. In the process, Mexican scientists and engineers were trained in the new technology so they could utilize the results of the studies and be self sufficient in utilizing remote sensing technology in other resource studies.

Later, based on these reconnaissance procedures, a generalized resource survey with ground checks was completed in southern Sudan by D.G. Moore and Associates from South Dakota State University. This survey of 160,000 km^2 provides certain soil, geology, vegetation and other data necessary to use in the analysis of resources. The survey was conducted and results were published in only 10 months which illustrates that basic data even in remote areas can be derived rather quickly. In areas where it is not convenient or possible to make detailed ground checks, the World Soil Map (FAO) provides much useful information which can frequently be improved upon by using satellite imagery.

Recommendations for Strengthening Research Groups

1 In addition to the permanent staff, provide for short-term positions by visiting scientists. Individuals on leave of absence from universities and industry in this country and from foreign governments can bring new ideas and enthusiasms into an organization.

2 If at all possible, defy the trend of many universities of permitting staff members to attend only a single national meeting and little else and many times having to personally bear a portion of the expense. In my opinion the best sabbatical you can provide for researchers and teachers is frequent attendance at professional meetings such as this one. Other useful examples:

Attend symposia
Consult for federal and international groups
Invite visiting scientists to give lectures
Accept speaking engagements to diverse groups
Write review papers and research papers

3 Adhere to reporting and research schedules. Universities are notorious for inability to adhere to tight project schedules. Teaching faculty are particularly noted for this fault, perhaps because they must regularly meet tight teaching schedules and thus may feel that they can let the research slide.

4 Nothing breeds success like success itself. Perhaps one-third to one-half of the rating in considering research or educational proposals is based on the reputation and capability of the individual and the department. Nothing does more to boost these ratings than a past record of successful completion of projects and timely submission of reports.

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5 Publish - avoid publish or perish pressure, but do not let reports to funding agencies be the final publication.

6 Write - write continually. We are in an era of short time fuses. It isn't uncommon to have a month or less to respond to a "Request for Proposal." I can recall when it was considered optimum to spend many months preparing, reviewing, rewriting, etc. proposals. Review the subject of your interest, write a comprehensive review, write on various facets of it. It is difficult to sit down and write coherently under pressure. If you write frequently at your leisure, you will find it easy to assemble a final product when the tight guidelines are laid down.

7 If you are an administrator - put your money on the winner.

8 Include all segments of a research group in the planning process. It is disconcerting to a data handling specialist, for example, to be asked to analyze inadequate data which he had no hand in planning.

9 Strive to overcome departmental and school rivalries in research. A research authority has said "authorities", "disciples", and "schools" are the curse of science; and do more to interfere with the work of the scientific spirit than all its enemies.

10 Seek to share physical resources and expertise with other universities and with researchers in government.

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NASA PROGRAMS IN TECHNOLOGY TRANSFER AND THEIR RELATION TO REMOTE SENSING EDUCATION

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INTRODUCTION

By charter, NASA is a research and development agency. Because operational responsibility for using the technology developed frequently rests with other organizations, technology transfer to those users has always been a central feature of NASA programs.

In each major area of responsibility, a variety of mechanisms has been established to provide for this transfer of operational capability to the proper end user, be it a Federal agency (e.g., in the case of weather satellites), industry (e.g., in the case of communications) or other public sector users (e.g., state government in the case of remote sensing). In addition, the Technology Utilization program was established to cut across all program areas and to make available a wealth of "spinoff" technology (i.e., secondary applications of space technology to ground-based use).

The transfer of remote sensing technology — particularly to state and local users — presents some real challenges in application and education for NASA and the university community. The purpose of this paper is to describe NASA's approach to the transfer of remote sensing technology and the current and potential role of universities in the process.

DEVELOPMENT OF REMOTE SENSING

NASA use of airborne remote sensors to assist in the solution of state and local government problems emerged from internal policy recommendations in 1970. Two years later, the systematic evaluation of satellite remote sensing capabilities began with the launch of Landsat 1 in 1972. Some 325 Landsat 1 investigations and over 100 Landsat 2 investigations were conducted under NASA sponsorship, largely by universities, to assess the utility of space-borne sensors for resource and environmental monitoring. They laid the basis for applications to follow, but were, in many cases, one of a kind activities.

A more comprehensive NASA program to verify the utility of Landsat data and further its adoption beyond the scope of basic R&D programs was undertaken

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*Presented at Conference for Remote Sensing Educators, Stanford University, Palo Alto, CA, June 27, 1978.

through the Applications Systems Verification and Transfer (ASVT) program, initiated in 1975. Now extended to technology areas other than remote sensing, 19 ASVT projects have been undertaken to date, providing in-depth proof of concept demonstration for a variety of technology applications in operational environments.

ASVT project selection criteria stress large-scale applications with major potential benefits, the use of demonstrated, but not necessarily fully validated technology, user commitment of resources, industry involvement, and a definite endpoint for NASA participation. ASVT's utilize a total "systems" approach to projects and are designed to address all factors that might affect eventual adoption of the technology for operational use, from technical soundness to cost benefit to institutional arrangements. Extensive documentation from these projects serves both to assist technology transfer to new users and to provide a source of verified applications to train resource managers in the use of remote sensing.

UNIVERSITY PROGRAMS IN REMOTE SENSING

Since 1974, the NASA University Applications program has supported the application and transfer of remote sensing technology by encouraging direct interaction between universities and state and local governments (figure 1). Programs begin with identifying users and problems and focusing on those problems where remote sensing can provide information needed to make specific resource management decisions. The program also serves to establish remote sensing capabilities within the universities that can continue to support users after NASA support has been phased out.

Since 1974, 26 schools (fig. 2) have been supported under a step-funded grant program that progressively builds capabilities in new geographical areas as previously supported programs became self-sustaining. As a side benefit, there has been a large growth in the availability of remote sensing education. In 1977, 137 courses were given to some 2,906 students with participation by the universities shown in figure 3.

A 1978 evaluation conducted by the Battelle Columbus Laboratories concluded that as a result of the program, state and local government involvement in remote sensing was growing, the program provided a nucleus for attracting independent support, and that the teaching of remote sensing was growing (fig. 4).

REGIONAL REMOTE SENSING APPLICATIONS PROGRAM

In 1976, the General Accounting Office (GAO), the National Conference of State Legislatures (NCSL), and the Space Applications Board (SAB) (a NASA advisory group under the National Research Council), recommended an increase and focus in NASA remote sensing technology transfer efforts, particularly to state and local governments. In response to those recommendations, the

Regional Remote Sensing Applications Program was initiated in January 1977. The goal of the program is to systematically transfer to state and local governments the ability to effectively use Landsat data for their resource and environmental management and planning decisions (fig. 5).

The program is remote sensing oriented and provides a more direct approach to assistance (including "hands-on" training) than had been the case in past NASA programs. A unified, national-scale approach is provided through three NASA centers, designated Regional Centers, serving as contact points for the states in their regions, and as locations where NASA could build on existing capabilities to provide the full range of user services required. The three centers are:

- The Ames Research Center — Responsible for a 14-state western region;
- The Goddard Space Flight Center — Responsible for a 19-state eastern region; and
- The National Space Technology Laboratories/Earth Resources Laboratory — Responsible for 17 southern and central states.

Other field centers provide liaison and information dissemination support to the programs carried out at the three Regional Centers.

The transfer objectives of the program are met through four specific types of activity (fig. 6) as follows:

User Awareness programs serve to inform decision makers and agency personnel about the capabilities of remote sensing and the experience of users elsewhere. Typical activities include workshops (such as a series of five workshops run by the National Conference of State Legislatures in 1977-78 for state legislators) as well as direct contacts with executive offices and state agency heads to inform them of remote sensing capabilities and to initiate planning for individual state programs. As of June 1978, working contacts have been established in 37 states, legislative workshops held in seven states and multi-agency workshops have been held in 19 states.

Training of state personnel with operational responsibility for resource management has two objectives. First, it is a necessary step in helping states acquire a remote sensing capability. Also, it prepares these personnel for direct participation in the demonstration projects described below. Presently, the three Regional Centers provide both basic and advanced applications training; eventually we envision all basic training to be handled by the states, probably through universities although that must remain the choice of the individual state. We are working toward this goal through the sponsoring of university-taught short courses to assist and promote the integration of remote sensing into undergraduate and graduate curricula, and through conferences like this one to encourage interchange of experiences and techniques in the teaching of remote sensing. Since January 1977, over 200 individuals have received basic and, in many cases, advanced technical training; another 250 managers and policymakers have received less intensive orientation level training.

Demonstration projects provide low-risk opportunities for potential users of remote sensing to evaluate specific applications in their own working environments. Because the end objective is operational use of remote sensing, demonstration projects must draw only on well proven technology, such as that from ASVT or maturing R&D programs. The objectives of the projects are to point the way to better use of available resource information and to provide the user with a basis for deciding if remote sensing can meet their operational needs. "Hands-on" user participation is a requirement to assure that the user has a first-hand basis for such decisions and projects are generally of a multi-disciplinary nature to provide as much of a cross-section of the potential range of applications as possible. The likelihood of a state deciding to establish an operational remote sensing capability is vastly increased if it meets a variety of needs rather than a single one. Demonstration projects of varying complexity are now underway in 14 states with another half dozen expected before the end of the year.

Technical assistance, the last area of activity, is perhaps the essence of actual transfer — a continuing interface with users establishing or operating their own capability to utilize Landsat. Activities include joint evaluation of state conducted projects, providing information on new technology and the building of user contacts with sources of services, hardware, software and other expertise outside NASA that can provide continuing operational assistance. Stimulation of private sector software, hardware and service capabilities is necessary as well as the building of links between the state agencies and universities for operating arrangements, technical advice and, where appropriate, operational support.

FUTURE DIRECTIONS

Turning to the future, there are two areas of activity that offer encouragement for remote sensing, one for the area as a whole, and the second for the university role in particular.

Because Landsat is an R&D program, continued availability of satellite data has never been guaranteed. In December 1977, a major step was taken toward assuring continuity of data with the Administration's decision to include a multispectral scanner on Landsat-D, thus providing continuity with Landsats-1, 2 and 3. In March of 1978, Dr. Frank Press, the President's science advisor and director of the Office of Science and Technology Policy (OSTP), requested a survey of state uses of Landsat by the Intergovernmental Science Engineering and Technology Advisory Panel (ISETAP), a committee created to advise OSTP on state and local government needs. The result was a strong endorsement for Landsat by state governments and a call for establishment of an operational system.*

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*Several months after this conference, in October 1978, the White House issued a U.S. Civil Space Policy Fact Sheet committing to "continue to provide data from the developmental Landsat program." The statement also gave NASA responsibility for chairing an interagency task force to examine options for integrating current and future systems into an integrated national system. Several bills have been proposed in the Congress to provide for immediate establishment of an operational system.

ISETAP found that some 35 states have used Landsat in 157 applications in the planning and management of resources with land cover inventories (18 states) and water quality assessments (16 states) being the most prominent uses. Although many of the cases cited were one-time uses, seven states have an operational Landsat capability, and 12 states legislatively recognize Landsat programs. Of the 28 states that have used Landsat in operational programs, a number are on the verge of full operational commitments. ISETAP estimated that by 1979, $9 million of state funds and $8.5 million of state-controlled Federal funds will have been used for Landsat programs with a definite rise in commitments expected in the future.

An analysis of barriers to expanded use of Landsat led to six recommendations shown in figure 7. The growing enthusiasm of the states for future use of remote sensing is implicit in the strength of the recommendations, many of which require national policy decisions beyond the scope of NASA programs. Prominent among the recommendations is the call for comprehensive and continuing Federal technology transfer programs — specifically to accomplish the types of activity that have been discussed above.

The panel also addressed the role of universities in the program, calling for their continued involvement in Landsat programs in providing remote sensing education, exploratory research, development of specific applications and data products, training of state and local officials, and providing consultation and advice. They did, however, acknowledge potential problem areas in that: (1) university roles have traditionally been oriented to R&D rather than the operational support called for in some cases; and (2) universities, particularly state universities, were frequently subject to political tensions that could affect their participation.

The OSTP's analysis of this report continues along with a broader evaluation of the institutional, technical, socio-economic and other issues central to the establishment of a national operational Landsat system, but the outlook is extremely promising.

The second area of major future interest to the university community is the recent establishment of a policy on academic involvement in R&D programs by NASA Administrator Robert Frosch; excerpts from this policy are shown in figure 8. The policy is directed to the basic research portion of NASA's discipline-oriented R&D programs and calls for "general strengthening of academic programs in creative and independent research in aerospace science and engineering." In brief, the policy brings renewed recognition of the fact that much of the nation's expertise for addressing the major unsolved problems in all NASA's R&D programs lies in the universities.

Specific plans for implementing this policy are still under development, but this affirmation of continued support for the active participation of universities in the NASA program augers well for the role of universities in the development of national capabilities for using remote sensing.

With that background, figure 9 outlines a number of specific future roles that universities can play in NASA's remote sensing programs.

Education, a primary university function, is a basic need in the process of technology transfer and universities must strengthen their capability for providing remote sensing education. Conferences such as this one can help to stimulate and reinforce that process, but the initiative remains with the university. NASA-sponsored short courses may encourage some general acceptance of remote sensing in new departments, but universities must also take initiatives to integrate remote sensing in existing curricula, and to use remote sensing both as a teaching tool and as a fundamental source of data for solving problems. Remote sensing will not entirely come of age until it becomes a natural and expected source of information in agriculture, forestry, hydrology, planning, and a host of other discipline areas that are the training grounds of future resource managers.

There is a need to develop new types of training material, and means must be established to provide for the continued exchange and shared use of materials. The definition of training requirements and identification of available training materials through the university-based Remote Sensing Science Council (established through the Western Regional Applications Program) are two steps in that direction.

The role of universities in NASA research is an important and growing one with increased opportunities to be provided through current mechanisms as the Applications Notice process and flight experiment solicitations and those new initiatives developed as a result of the academic involvement policy referred to above. The University Affairs Applications Program will continue to build university capabilities in remote sensing to meet state resource management needs, in coordination with the statewide activities being developed through the Regional Remote Sensing Applications Program.

Turning to technical opportunities, there remains a major need for better processes to extract information from sensor data; that step, of transforming data into information, is the critical step in making remote sensing accessible for operational use. Another area of growing importance to resource management is that of geobased information systems. Landsat, or any remote sensor, is but another source of information. Used alone, that information is of limited value, but when systematically combined with information from other sources, using the immense data processing capability of digital computers, the value and utility of the data is enhanced many-fold. Much remains to be done, both to further develop information systems and to optimize the interface of remotely sensed data with these systems. Much (but not all) of this work is of a development nature rather than basic research, but it represents the kind of technology that must be available for transfer in the next few years if remote sensing is to realize its true potential.

User training is likely to remain a major area of direct university assistance to state programs. Basic training in remote sensing is a transitory part of the NASA program, and rapid assumption of that function by universities and other qualified sources will hasten the ability of state programs to become self-sustaining.

Where remote sensing programs are established in state governments, universities will continue to be relied upon for technical assistance in applying the technology to traditional areas such as agriculture, forestry, etc., as extensions of current cooperative programs with state agencies.

Finally, substantial opportunities may exist for universities to provide operational support to the comprehensive resource management programs now evolving in the states. The degree to which university capabilities are utilized depends on policies of the state and its traditional relationships with its colleges and universities as well as the degree to which universities can and are prepared to adopt operational roles in many cases quite different from traditional research roles.

The education and training of resource managers to help them understand the value of remote sensing and then to begin relying on it as a dependable and valuable source of information, is a job that we are, in many ways, late in starting. Universities have much to contribute, and we look forward to your active participation in building capabilities for what promises to be one of the most significant information explosions of the decade.

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OFFICE OF UNIVERSITY AFFAIRS

University - Space Applications

Forms of Interaction

Institutional commitment to public service

Identify state and local problems which remote sensing can help solve

Assist potential users to learn how better to use remote sensing

Conduct remote sensing applications programs to bring remote sensing technology to bear on the solution of selected problems

Stimulate, guide, and aid the faculty and students and others in the state to utilize information from the NASA earth resources satellite and aircraft flights in research and public service activities

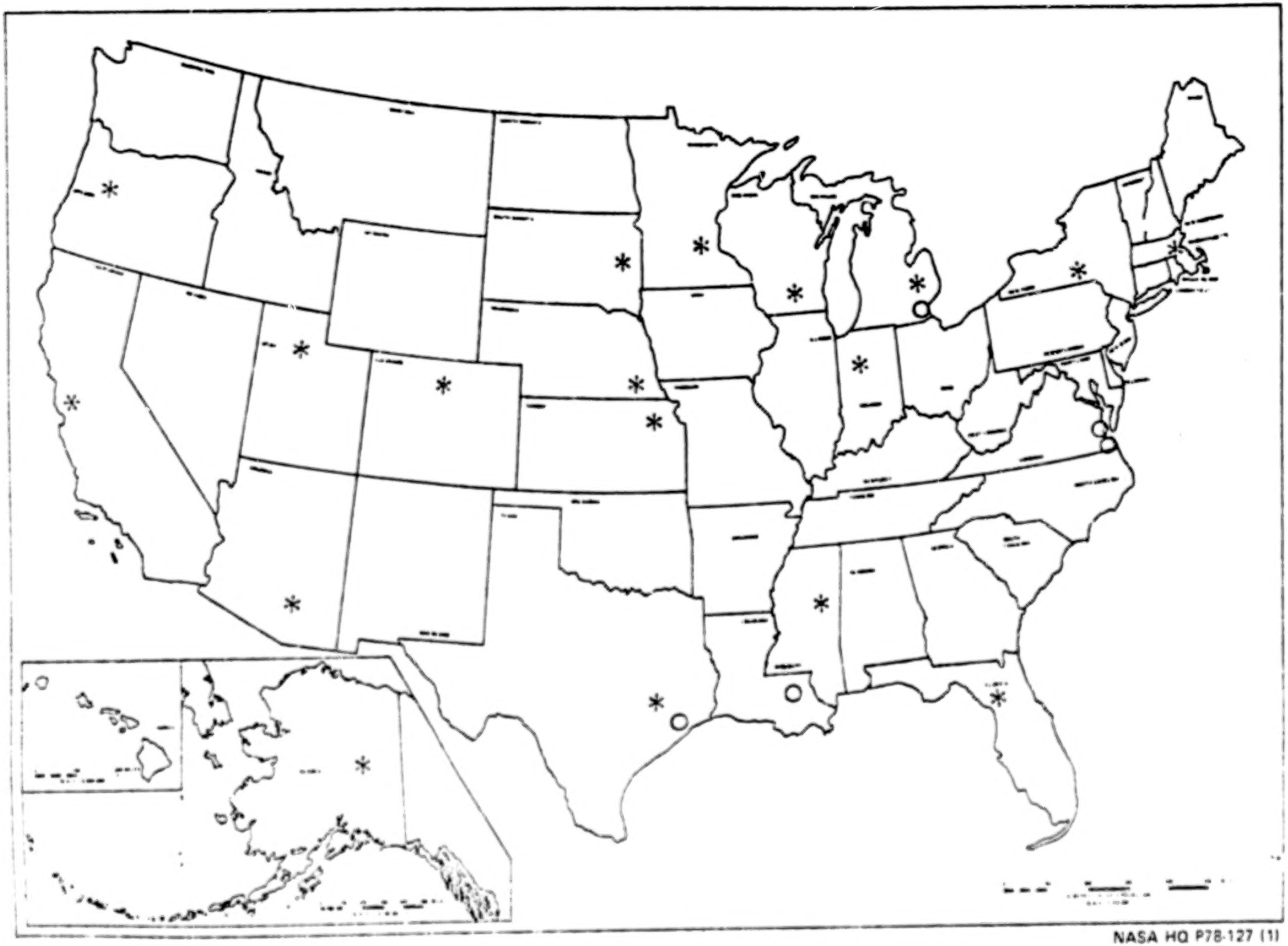
Provide a center of expertise and an operational laboratory for short course training and assistance in solving problems

Make certain specialized equipment and images available to users

2/20/73

Figure 1

SPACE APPLICATIONS PROGRAM
FY 1977



NASA HQ P78-127 (1)
10-12-77

Figure 2

STUDENTS AND COURSES IN UNIVERSITY REMOTE SENSING PROGRAMS

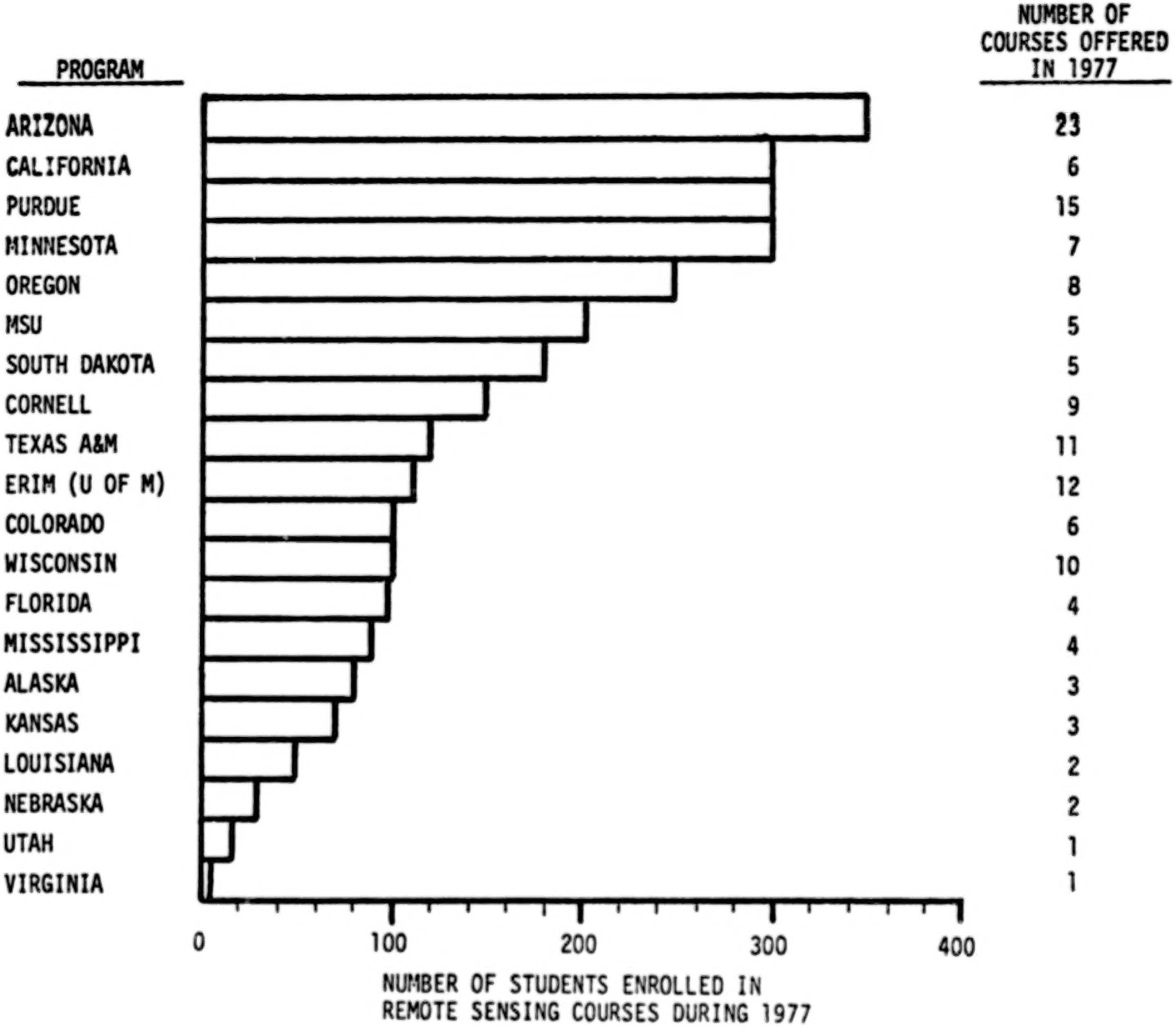


Figure 3

UNIVERSITY PROGRAMS IN REMOTE SENSING

CURRENT OBSERVATIONS

- ALL OF THE PROGRAMS HAVE ATTAINED SOME LEVEL OF STATE/LOCAL INVOLVEMENT
- SUCH INVOLVEMENT DEPENDS ON SEED MONEY TO DEMONSTRATE APPLICATIONS BEFORE STATE/LOCAL AGENCIES WILL PROVIDE FUNDING. STATE/LOCAL FUNDING HAS INCREASED FROM $258,000 IN 1974 TO $985,000 IN 1977.
- 2/3 OF THE PROGRAMS HAVE MINOR PRIVATE SECTOR INVOLVEMENT
- UNIVERSITY PARTICIPATION IN REMOTE SENSING IS LARGE AND GROWING. OVERALL DURING 1977, 137 COURSES WERE TAUGHT TO A TOTAL OF 2906 STUDENTS. 195 FACULTY MEMBERS AND 393 RESEARCH ASSISTANTS WERE INVOLVED IN THE RESEARCH PROJECT.

Figure 4

GSFC
TECHNOLOGY
NASA HQ

Figure 5

REGIONAL REMOTE SENSING APPLICATIONS PROGRAM

OBJECTIVE	APPROACH
USER AWARENESS	CONTACT AND ORIENTATION OF DECISION MAKERS AND OPERATIONAL PERSONNEL
TRAINING	"HANDS-ON" TRAINING TO ENABLE KEY PERSONNEL TO UTILIZE TECHNOLOGY
APPLICATION DEMONSTRATIONS	COOPERATIVE PROJECTS TO PROVIDE LOW RISK EVALUATION OF REMOTE SENSING CAPABILITIES
TECHNICAL ASSISTANCE	FOLLOW-ON CONSULTATION WITH USER AND STIMULATION OF NON-FEDERAL SOURCES

Figure 6

ISETAP RECOMMENDATIONS

- FEDERAL COMMITMENT TO DATA CONTINUITY AND COMPATIBILITY
- FEDERALLY SUPPORTED SYSTEM - VIEW AS A PUBLIC SERVICE
- DEFINE FEDERAL AGENCY RESPONSIBILITIES - LEAD AGENCY NEEDED
- FEDERAL COMMITMENT TO INVOLVE STATES THROUGH REPRESENTATIVE BODIES
- COMPREHENSIVE AND CONTINUING FEDERAL TECHNOLOGY TRANSFER PROGRAM
  AWARENESS, TRAINING, DEMONSTRATION, ASSISTANCE, DEVELOPMENT
- IMPROVED DATA PROCESSING AND DELIVERY SYSTEM

Figure 7

POLICY FOR ACADEMIC INVOLVEMENT IN THE NASA R&D PROGRAM

- ACADEMIC SCIENTISTS WILL CONDUCT A SUBSTANTIAL PORTION OF THE BASIC RESEARCH IN ALL DISCIPLINES IN THE NASA PROGRAM
- ACADEMIC SCIENTISTS WILL PARTICIPATE. . . IN ALL PHASES OF BASIC RESEARCH
- ACADEMIC BASIC RESEARCH GROUPS WILL BE ENCOURAGED TO SHOW INDEPENDENCE AND CREATIVITY IN THEIR WORK
- BASIC RESEARCH OPPORTUNITIES USING SPECIFIED NASA SPACECRAFT WILL BE AVAILABLE
- NASA'S RESEARCH FACILITIES WILL BE AVAILABLE FOR BASIC RESEARCH. . .
- COOPERATION IN BASIC RESEARCH. . . WILL BE ENCOURAGED
- CONTINUING PROGRAMS WILL BE SUBJECT TO PEER EVALUATION AT LEAST ONCE EVERY THREE YEARS
- NASA'S RELATIONS WITH THE UNIVERSITY COMMUNITY WILL BE CONDUCTED IN A MANNER THAT REFLECTS CONCERN AND UNDERSTANDING FOR THE ROLE OF UNIVERSITIES IN EDUCATION AND RESEARCH. . .

Figure 8

UNIVERSITY PARTICIPATION IN REMOTE SENSING PROGRAMS

EDUCATION

FACULTY FAMILIARIZATION - WORKSHOPS, SYMPOSIA, CONFERENCES
INTEGRATED CURRICULUM DEVELOPMENT
TRAINING MATERIAL DEVELOPMENT/EXCHANGE

RESEARCH

PARTICIPATION IN THE APPLICATIONS NOTICE SELECTION PROCESS
- RESEARCH, TECHNOLOGY DEVELOPMENT

UNIVERSITY AFFAIRS SPACE APPLICATIONS PROGRAM
- DEMONSTRATION OF PRACTICAL BENEFITS
- ESTABLISHMENT OF CAPABILITY FOR ASSISTANCE

AREAS OF GROWING IMPORTANCE
- INFORMATION EXTRACTION PROCESSES
- INFORMATION SYSTEM DEVELOPMENT AND APPLICATIONS

STATE ASSISTANCE

TRAINING OF USERS
TECHNICAL ASSISTANCE - SOURCE OF EXPERTISE
SYSTEM OPERATIONS - AS DESIRED BY STATES

Figure 9

NASA'S WESTERN REGIONAL APPLICATIONS TRAINING ACTIVITY

Charles E. Poulton
Training Officer
WRAP

Ladies and gentlemen and colleagues, the title of my presentation might lead you to expect that I am going to stand up here, at this early point in the Conference, and tell you all the great things that the training component of the Western Regional Applications Program is doing to support the demonstration projects and to foster a more effective technology transfer in this important and dynamic field of remote sensing. This is not my purpose, although the full staff at Ames is working very hard to achieve these goals in some sectors, and to increase the total capability to achieve them in all areas.

We have a concerted program of demonstration and training-related activity going on in six of the states in our 14-state Western Region and some limited activity in a couple of other areas. I do not, however, wish to lull you into the feeling that this is enough or that we have all the answers as to how it should be done. We need your help most critically because the job is not getting done anywhere near in proportion to need. We do not yet have a critical mass of manpower and resources devoted to this effort, and we do need to think through and formulate a stronger cooperative program with the educational institutions in the region.

One of our goals is to increase your direct involvement in transfer of the latest technology within the states and ecological regions that you represent. An intermediate goal is seen in one of the primary purposes of CORSE-78--namely, to get you people from the educational institutions involved in helping us to formulate a sound, education/training program and to clarify or specify the roles that the educational institutions, NASA and other government agencies, and the involved segment of industry should play in achieving the standards of education and training to ensure that technology transfer will keep pace reasonably well with the advancements of the art and science of remote sensing.

Since I have been involved personally in the program for quite a few years, I do have a few ideas that I want to share with you--hopefully as a stimulus to your further analysis of the problems, challenges and opportunities. I also wish to give you a quick rundown on some of the policies, guidelines and concepts under which I believe that an expanded and improved training program should move ahead. I shall, as well, pose a number of questions for your contemplation. It is my intention to give you a background in how we are thinking at the present time which, hopefully, will serve as a launch platform for your collective contributions during this Conference.

As you have already been told, the central purpose of the Western Regional Applications Program is to stimulate appropriate use of LANDSAT technology by state and local governments. This is being done initially through demonstration projects but with a longer term goal of finding and identifying those uses and methodologies which do have a continuing and worthwhile role to play in resource allocation, development and management and thus, in the improvement of human environment at state and local levels.

We hope to bring about some re-adjustment of the proportionate distribution in the use of LANDSAT imagery--with less than 2 percent presently being used by state and local governments and only about 10 percent being used by colleges and universities.

First, let us consider, "What is the problem, and what are some of its possible causes?" With these identified, perhaps we can initiate a corrective strategy.

I presume most of us would agree that, on the average, among people who should know the state-of-the-art in the remote sensing of earth resources and human environment there is a substantial lag in real application. That is, too many people are working too far behind the forefront of technological capability, even within the academic institutions. If this is true, then it follows that we cannot hope to catch up in the continuing education and training of professionals already on the job until after the universities themselves have incorporated state-of-the-art training into their curricula and new graduates are less in need of an update.

Following are some of the reasons why I think we face this challenge. Some of these may give us a clue to ways in which we can meet the challenge we face in education and training.

1. The science and technology is a very rapidly, advancing area. At best, it has always been a challenge to keep up, even for those institutions deeply involved from the early development.

2. There has been a slacking off of support and of involvement by the universities since Skylab, i.e., dollars for involvement have not been there.

3. In the early development years, a relatively limited number of universities became identified by both design, chance and performance as the leaders in the field of new remote sensing technology, often with very high levels of specialization as certain of these institutions were involved in specialized facets of the technological development. This lead to a situation where the "in's were in" and the "out's were out,", although in recent years most of these universities have also been very deeply involved in training programs which have tended to expand the horizon of competence, as did the ERTS-I, II and Skylab experiments.

4. In most universities where remote sensing is taught, it is covered in one, two or three departments, generally with a very strong disciplinary orientation. When one comes to LANDSAT and related technology, a multidisciplinary involvement is often essential because the applications tend to be broader in scope and perspective, even though single discipline applications are still appropriate. Are departmental jealousies and prerogatives a hindrance to expansion and development? If they exist in relation to full development of remote sensing education and training, how can we change these attitudes and interests into a motivating asset?

5. Use and application of satellite imagery in practical earth resource problem solving requires some new orientation of thinking and, for many, a new conceptualization of methodology. Many natural resources decision-makers, managers and staff

people have certain understandable preferences for the higher resolution photography to which they have been accustomed. This makes it difficult for them to make the necessary transition and often to conceive how the new LANDSAT imagery can be useful to them. The solution of this problem similarly lies in the area of information, education and successful demonstration.

6. The demand for students trained in the technology which reflects back from employers to the universities may not be high enough to put remote sensing training in the priority that we would like. We are all well aware of the extreme difficulty of getting any new curriculum or even new courses approved in the normal university or college administrative and fiscal atmosphere, and recent enrollment shifts have complicated rather than ameliorated this problem. I would like to dwell on this point a moment.

Perhaps we have one of the proverbial "chicken and egg" problems. Is there a demand within your state for a higher level of involvement on your part, the educational institutions, in providing education and training in these new and particular technologies? With state and local use being as low as it is, there is little likelihood that there is pressure, concern or interest emanating from the state and local agencies to employ students who have this particular knowledge and the supporting skills. Similarly, with 23 percent of the use being made by federal agencies, how much of this is telegraphing back to your institutions a need and demand for increased training above and beyond traditional photo interpretation and photogrammetry? Perhaps some of you are heavily involved in foreign work. Here, I should imagine, you are encountering some degree of interest and pressure to provide training or expertise in the application of this new technology as part of the solution to economic development and refinement in the handling of natural resources by developing nations. But what is the net effect of these demand factors in molding your institutional priorities for the improvement in education/training and technology transfer? Is a low level of demand part of the dilemma we face in achieving education/training goals? I suspect that it is. Where lies the key log and how large will the charge have to be to break it loose so that we can get the full benefit of the technology moving on down the river?

In addition to the aforementioned pressures and encouragement from agencies within the state for its universities to increase their involvement in remote sensing training, there is another thing that has to happen as a prelude to action. This brings us to the next causal factor.

7. The university administrator, chancellor or governing body must realize that this need is an essential part of service to the state and also be aware of the importance and potential rewards to the university of accommodating that need. Until new programs or program expansion is sufficiently high on the priority list of the college and university administrator, nothing is likely to happen, in spite of faculty interest. If this is a valid

> assessment of one phase of the challenge we face, then are there some things that we from NASA and the WRAP program can do to help ease your burden and challenge as faculty? We have envisaged the possibility of a systematic program of contact with appropriate university administrators or governing bodies with a view to presenting the needs, opportunities and capabilities of state-of-the-art remote sensing technology. We need your guidance. Is this an activity that would be helpful and shall we become engaged in it?

With this partial picture of where we stand, I would like to move now to a few important guidelines and concepts for the training program as we see it.

Starting with the design of the WRAP demonstration projects and following through to their successful conclusion, it is imperative that those directly involved be particularly knowledgeable about the capabilities and limitations of the LANDSAT system, how it can most effectively interface with conventional methods, and, in a nutshell, how to execute a thoroughly successful demonstration project which makes use of LANDSAT technology where and in a way that is appropriate. We have approached these problems now in 6 of the 14 western states, and we find that the requirement for short-course training is real and urgent once a demonstration project is conceived. Too few of the people now actively working in their respective professions with state and local agencies have adequate training and familiarity from their prior college and university experience to step into and successfully carry out a demonstration project without substantial assistance, close guidance and some help all along the way. Thus, it appears imperative that steps must be taken to make additional short-course training available within the participating states until such time as their own universities, state colleges and community colleges can tool-up to carry the load--recognizing also that tooling-up implies a financing mechanism as well.

In meeting this immediate challenge through the training element of WRAP, NASA has no intention of usurping or permanently taking over the respective roles of these educational institutions. Our near-term involvment is purely and simply a stop-gap but, hopefully, also a stimulus. Our policy is one of getting out of training and education in the well-established and proven areas of the technology--in fact, staying out initially wherever local, educational institutions are in a position to meet the immediate needs. Where institutions are interested in acquiring the capability to take on this responsibility within the state, it will be our policy to work closely with them, to the limit of budgetary and staff resources, and with a view to realizing some permanently beneficial spin-off to local educational capability from each and every demonstration project. We are already following a policy of putting on short-course training in close collaboration with local educational institutions--as exemplified in our training course this month at Montana State University. The local staff carried all of those elements of training in which they felt comfortable. We conducted the rest with our staff; and together we apparently provided a reasonably successful short-course training program to kick off the Montana Demonstration Projects. Everyone grew as a result of the experience. This exemplifies one of the patterns we would hope to follow. We are looking to your participation in this Conference to give us some guidance as to how we can be even more effective in working toward these goals.

We see the continuing and long-term role of NASA in the education/ training field as eventually being restricted to the forefront of new technology. We would like to create a situation where, in this involvement, we are working almost exclusively through the local educational institutions. Our goal would be to bring and keep them up-to-date in the expanding technology so that even here our primary challenge is in transferring the technology and capability to university staff and ensuring that they have the facilities, proportionate to state demand and need, to provide education and training at the operational forefront of the developing technology.

To meet immediate needs, we believe the best job of training can be done when short courses are individualized to meet the specific needs of state demonstration projects; but we believe these can still be designed sufficiently in the context of basic principles to have real educational value. Design of training to match the demonstration project generally requires only sound decisions on what to leave out in the interest of available time and training needs. Whenever possible, training will be done with laboratory exercises taken from or near the demonstration project area.

We are devoting substantial time and effort to the development of specific training modules which can be used repeatedly for reinforcement of learning, for clarification, and in a self- or programmed-learning mode. We have already begun to put these together and are maintaining a close liaison and working relationship with the Applications Group at the EROS Data Center on such matters. The modules will consist primarily of carefully prepared visual aids for lecture support, slide-tape and video tape units, carefully prepared lesson plans, laboratory exercises and possibly computerized, programmed learning units for certain demonstration and training elements.

To enhance the quality of training offered at the Ames Research Center, we have designated a local laboratory-demonstration area consisting of two adjacent LANDSAT scenes extending from the coast eastward to the Sierra forested region. Laboratory exercises and demonstrations developed in this area will include both visual and computer analysis of LANDSAT, supporting highflight and conventional photography and eventually cover a broad array of multidiscipline applications. Initial developments in all these areas are in response to the requirements of specific training programs; but we expect to prepare a reasonably complete set of support materials for education-training and that they will be exportable to other institutions for their use or as a pattern for preparation of local material.

For training on the computer science side of imagery analysis, we consider two guidelines important. First, the most effective training that we and the educational institutions can provide is in the generic context of principles, approaches, understanding of work flow, critical pathways and algorithms rather than in the mechanics of specific software/hardware systems. We have tried the latter and found it impossible to keep up with modifications in some systems. In addition, it is impossible to predict the direction users will go as they select or modify supporting computer systems. Thus, the training goal should be to provide a sufficiently sound background that users can go any desired direction in software and system-specific operation. I imagine we are in agreement with many of you that better operator-user manuals are required for specific systems and that it is imperative to keep these reasonably up-to-date. We have come to the conclusion that, to the extent these manuals are essential, they must be the responsibility of the proponents of the software/hardware system and that system-specific training is best given in small groups on an operational workshop basis after the training in principles and theory.

Secondly, trainees in computer analysis fall into two important groups, each with its own unique requirements for training, understanding and skill development. These are: (1) The computer scientists and technicians who punch the buttons and make the system work, and (2) the users of information with their support staff who make a different kind of input to the operation of the analytical system. The interest of this latter group is primarily or exclusively in the information output, what it can do to make their jobs easier, and how they can use the information better to achieve their goals in management. The elements covered, depth of treatment and training emphasis are unique to each of these groups. Both planning and presentation must be responsive to their separate needs and roles in data analysis. While these differences might be ignored in the captive audience of the academic classroom and curriculum, they must be recognized when working with user groups already on the job.

Finally, one last guideline--in some quarters, remote sensing seems to mean different things to different people. We feel that training should present remote sensing as an integrated system of elements appropriate to the requirements of the data to be obtained. We should avoid presenting multispectral, digital satellite data systems as a stand-alone element for two reasons: (1) We need always to take the trainee from where he is to where he wants to be. This transition is easiest if made from photo interpretation to digital analysis of multispectral/multidate data; and (2) the strongest and most efficient information system is often a combination of visual interpretation, computer analysis, aircraft photography, low elevation aerial observation and ground measurement. Thus, training should usually provide background and appropriate skills in both the visual and computer approach and in the options for matching from among all the above system elements when solving information problems through remote sensing.

Finally, I have one last challenge to lay before you--on which to ask your contemplation during the Conference and your advice. Does attainment of essential goals in remote sensing education and training require some re-orientation, expansion of change of emphasis in the NASA University Affairs Program as it has functioned to date? Should the University Affairs Program include a stronger element related very specifically to instruction? What should be the role of the universities in new research and development? Was this prematurely cut off or too severely restricted with the conclusion of the Skylab Program? Should the present applications emphasis of the University Affairs Program be continued as one of its elements? As I personally view the problem, NASA's University Affairs Program could consist of three very important elements; and I would put these in the following priority order:

(1) Stimulation, development and offering of new courses and/or curricula, short courses and technology transfer through regular academic programs, cooperative extension and continuing education;

(2) Research and development on new or persistent technological problems that have arisen directly from attempted application and demonstration projects--that is, R&D focused

on expanding the capacity and refining the capability beneficially to use the existing satellite hardware and data systems;

(3) University-lead demonstration projects designed to pilot tests, new applications of existing technology and especially of refinements developed through the R&D in topic 2 above.

This in total might be a larger program than the Congress, state legislatures and the American people would be willing to support at each and every interested university or college. Assuming this to be the case, how would you scope the program and where do you set the priorities?

As we bring new colleges and universities into the program, one of the greatest risks, and the challenge that I see, is to prevent the tendency to re-invent old wheels because of lack of information. This suggests then, that one of our very important, near-term programs should be expanded training for academicians who may become involved as instructors, as new R&D scientists or as new demonstration project leaders. What form should this kind of training program take? Who should design it? Where should it be conducted? What should the prerequisites for participation be and how much depth of training is necessary to ensure success? What is the faculty demand for this kind of training? These are some questions that we look to you to help us solve.

Scattered throughout the Western Region there are a number of educational institutions in an ideal position to help implement this kind of educational program for the academicians. Many of you can name them as well as I. Just to mention a few, the University of California at Berkeley, Santa Barbara and Riverside; University of Arizona; Colorado State University; South Dakota State; and Oregon State University. At the risk of stopping here and reaping condemnation on myself, we would like to know if universitites such as these are in a position now to pick up and carry the load of further instruction for their academic colleagues with the goal of really bringing them to the forefront of technology? Can this be done with present resources, facilities, and staff? If not, what are your needs and what is the best way to put a few of these already established lead universities in a position to help us quickly make the transition, catch up and move on over greater horizons of opportunity in remote sensing applications?

As a mechanism for more effectively interacting with the educational community, we hope to see the acceptance and organization of a University Remote Sensing Science Council. A small committee headed by Dr. Jack Estes has been working on this idea for some months. They are holding a series of evening meetings during this Conference to further the work. Many of you have or will be contacted by this group and we encourage your participation so that such a Council, if formally organized, will be truly representative of the educational institutions throughout the Western Region.

In summary, new remote sensing technology has a substantial, generally unrealized potential to help state and local governments do a better job in many areas of land use and natural resources development and management. Progress in expanding this use in appropriate areas is slower than many of us would like because we sincerely feel it has the potential of increasing the efficiency and effectiveness of local government in these areas. One of the major reasons seems to be in the lack of information and education and of highly successful, well-publicized and effectively-used demonstration projects. We do not have a critical mass of manpower and resources going into awareness, education and training in this area. How can we bust the log jam loose and get moving? We need your thoughts, ideas and recommendations; we need the involvement of more of you and more involvement by those of you who are already in the act. What does it take to get from here to there? With the hope of finding answers to this and many of the other questions I have posed in the past few minutes, we are looking forward with great anticipation to CORSE-78 as a mechanism for answering some of these questions and finding solutions to the challenges we face in remote sensing education and training. We want and need your help!

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OPPORTUNITIES AND PROBLEMS IN INTRODUCING OR EXPANDING THE TEACHING OF REMOTE SENSING IN UNIVERSITIES

by
Eugene L. Maxwell
Colorado State University

A Paper Presented at the Conference of
Remote Sensing Educators, June 26--30, 1978
Stanford University, Palo Alto, California

INTRODUCTION

Most federal and state agencies, some levels of local government and certain parts of industry would agree that remote sensing will be an accepted source of environmental and resource information in the future. In many instances it is being adopted as a routine source of information today. It is widely recognized, therefore, that the universities and colleges across our nation must increase the number and quality of remote sensing courses at both the undergraduate and the graduate levels. This paper explores some of the problems and opportunities associated with the development of remote sensing education in the universities.

At the heart of most of the problems is the multidisciplinary nature of remote sensing. Because of the many disciplines involved in the design, operation and use of remote sensing systems, the academic community is having a hard time defining or even accepting a remote sensing program. This paper addresses this and other problems and then makes some specific suggestions relative to sources of funding, teaching materials, etc.

A BIT OF PHILOSOPHY

There is currently a debate about the need for degree programs in remote sensing. The issue actually goes deeper and questions the legitimacy of such a degree. Remote sensing is said to be only a means to an end (actually a variety of ends) and is, therefore, only a tool. The implication is that we are training technicians or, at best, that we are training professionals to use a new tool.

Certainly the photointerpreter is primarily a technician, and when we train the professional to follow cookbook procedures to extract information from an image, we have not taught him the science of remote sensing. Probably most of the courses in the universities today do just that, in part because they are taught by professionals who know remote sensing only as a tool, and in part because there have not been textbooks available to teach the science of remote sensing. Books are in preparation at the present time which will solve the latter problem, but the modification of our attitudes about remote sensing will be more difficult.

The multidisciplinary nature of remote sensing is given as another reason that degree programs may not be legitimate. For an undergraduate program, this is a reasonable argument. It would be very hard to design a four-year curriculum to teach all of the subjects encompassed by this field. For a graduate program, particularly a Ph.D. program, we should reconsider.

What is a Ph. D.?

The Doctor of Philosophy degree is so named because the early scientists (Aristotle, Pliny, Leonardo de Vinci, Copernicus, Kepler, Galileo and many others) were as much philosophers as they were scientists. They were as much into metaphysics as physics. These early scientists were not narrow specialists; even in the nineteenth century and early twentieth century, scientists worked in many fields. James Clerk Maxwell was involved with electromagnetics, heat, photography, dynamics of gases, and many other things. Similarly, the studies of Faraday, LaPlace, Planck, and many others were broad in extent. Neither did these men forget the importance of seeking an answer to the "why" of things. They were still part philosophers, and they were scientists working in several disciplines.

The Remote Sensing Specialization

It is true that remote sensing finds its justification in applications to many other disciplines. This is not, however, particularly different from the field of engineering. Engineers apply their science or technology to the design of equipment, facilities and structures for the use of others. For the most part, civil engineers do not design bridges for use only by civil engineers nor do electrical engineers design generators and motors which serve only the field of electrical engineering.

The only difference between the engineer and the remote sensor is the nature of and the demand for their products. The engineer produces equipment and facilities for which there is a great demand. Few people question the need for this product, and they fully recognize they cannot provide it without his assistance.

On the other hand, the remote sensing expert provides information, which most of his customers think they may be able to supply better in some other way. Hence, the demand for the remote sensing product has been slow in developing and in many instances his potential users find remote sensing to be a threat to their ego. It is interesting to recall that Thomas Edison considered engineers to be only a necessary evil. He resented the fact that he needed them to turn his ideas into practical devices. Perhaps in time the information specialist will be accepted as completely as is the engineer today. In the meantime, the education of remote sensing specialists will remain a questionable, almost clandestine operation.

The Complete Remote Sensing Scientist

The complete remote sensing scientist should know a great deal about:

Electromagnetic Field Theory
Optics
Quantum Physics
Biological Processes
Atmospheric Radiative Transfer
Geomorphology
Plant-Soil Relationships
Computer Science
Information Theory
Photography
Photogrammetry
The Information Needs of His Users

Obviously the remote sensing specialist is not being trained by any other discipline. If we could train this remote sensing specialist, he would have a broad knowledge of science, would be a specialist in the information collection field and would understand the needs (and philosophies?) of his customers. How better could we define a modern Doctor of Philosophy?

DEVELOPING REMOTE SENSING EDUCATON

Even if we should agree that there is a need for a Ph.D. program for remote sensing, we will still be faced with two major problems: 1) We are not sure how to train him and 2) the need for a specialist is still very small. It is apparent, therefore, that most remote sensing education programs will remain application oriented and only a few are likely to move toward remote sensing as a separate specialization. Nevertheless, we will discuss both the discipline and the specialization options for remote sensing education, and we will leave it to the faculty of each department and college involved to determine which type of program best fits their needs and capabilities.

The Discipline Orientation

If a university chooses to develop remote sensing education around existing disciplines, this can be undertaken by introducing remote sensing into the appropriate discipline oriented courses or by developing special courses which emphasize remote sensing applications to a specific discipline. For instance, courses in Geology, Archeology, Forestry, Hydrology, et al often contain a few lectures in the use of aerial photography. This material could be expanded to include satellite, radar, and thermal infra-red imagery, but it is doubtful that most courses can accommodate many lecture hours that are peripheral to the primary course objectives. For this reason, we cannot encourage a program which is limited to this approach. If this approach is combined with even one basic introductory course in remote sensing, then it might prove to be quite effective. That is, it will be effective _if_ the basic remote sensing course is a prerequisite to the other courses.

If the students entering a discipline oriented course have had the basic remote sensing course, then the instructors may concentrate on the specific applications of remote sensing to that discipline, without having to spend any time on the basics of aerial photography, stereoscopic viewing, photogrammetric measurements, etc. This should make it possible to discuss any of the pertinent remote sensing systems which might be applied to a particular problem.

Finding a remote sensing specialist to teach a general remote sensing course will be the primary difficulty encountered in implementing a program such as we have just described. It is unlikely that existing faculty, even though they may have used aerial photography or satellite images for their discipline, will be prepared to teach a general course in remote sensing. This problem can be solved, however, if a member of the faculty is willing to take special training. Establishing special training programs to accommodate this need should be undertaken in the near future, with the assistance of the regional NASA centers.

The program just described is not ideal because it is still very likely that the basic remote sensing course will have a strong emphasis toward the discipline from which the instructor has come. This may make the course not acceptable to other departments, who might otherwise want to introduce remote sensing into their course offerings. A more ideal solution would be attained if a remote sensing specialist were hired by one of the departments, with the understanding that several remote sensing courses would be offered.

One should note that the hiring of a remote sensing specialist does not create a program for training remote sensing specialists. This is still a discipline oriented program, but the primary instruction is being undertaken by specialists in the field of remote sensing. It is very likely that the courses developed under a program of this type will be team taught, with the remote sensing theory being taught by the specialist and the applications information being taught, at least in part, by faculty from other departments.

This type of program has the advantage that the equipment and other resources required for a really high quality educational program can be made available to several departments and colleges. Of course, this requires some sharing of equipment money and facilities, if it is to be equitable for all of the departments and colleges involved.

The final problem to be carefully considered is the selection of the department within which this program will be housed. With the shortage of resident instruction funds that exists at most universities, there may be some hesitancy to commit funds to a program not totally oriented towards the major department discipline. Ideally, the resident instruction support should come from all of the departments and colleges involved and then the selection of a department to house the program will be based only on convenience or interest.

The Remote Sensing Specialization

Remote sensing specialists could be placed into two basic categories, systems engineers and applications specialists. The systems engineer or optical physicist is needed to design the hardware which will be flown in an aircraft or a statellite. This type of specialist is being trained by numerous engineering and physic departments across the country. He may not be trained specifically to design remote sensing systems, but most optical physicists and/or electronic systems engineers can learn the remote sensing specialization without a great deal of difficulty. Our concern is not the training of these specialists, but rather, we are concerned with the training of the remote sensing applications specialist.

Specifically, we need to train remote sensing specialists who can communicate effectively with both the engineers and physicists who design the systems and the geologists, biologists, hydrologists, entomologists, et al., who will be using remote sensing data as a basic source of information. The question may be asked, "Can any one person be trained to communicate with all of the discipline specialists?" The answer to this question must be, "No." Many remote sensing specialists can discuss applications of remote sensing at an introductory level with most, if not all, of the disciplines. Really detailed discussions, however, (which will be required for many applications) are beyond the capability of any one person.

Therefore, a department undertaking the development of a program to train graduate level remote sensing specialists should be prepared to accept students from many disciplines. The program at Colorado State University has students from background as diverse as geology, fisheries and wildlife, forestry, geography, civil engineering, computer science, et al. A department which is used to having all of its students well trained in its basic discipline may have difficulty in relaxing requirements such that students from a wide range of disciplines may be accepted. Certainly, there must be some requirements in the areas of physics, chemistry, mathematics and statistics, and computer science. Discipline requirements, however, must be minimal.

In a program of this type it is likely that most master of science students will be training to specialize in the application of remote sensing to their particular discipline. Ph.D. candidates, on the other hand, may be training to carry out research in a remote sensing laboratory or to teach and undertake research in academia.

The department or college which provides a home for this kind of remote sensing specialization program must be willing to devote facilities and several faculty positions to this field. The department should, of course, be one which will make extensive use of remote sensing in its other disciplines. It must be genuinely interested in multidisciplinary education and research.

Since most departments will not have unlimited support for their remote sensing programs, a decision must be made relative to the emphasis which the program will have. Faculty members could be hired to provide emphasis to any of the following five areas: 1) computer analysis, 2) photointerpretation, 3) photogrammetry, 4) physical principles, 5) engineering and design. It is possible that all five of these capabilities could be covered by two or three people. Finding such people, however, will not be particularly easy. Hence, if the program is to be undertaken with only two faculty members, it is likely that an emphasis will have to be placed on two or three of the above areas.

In the opinion of this author, any educational program which wants to make claim to the training of remote sensing specialists must include expertise in the physical principles upon which remote sensing is based. These physical principles dictate the limits of engineering and design, computer analysis, photogrammetry, and photointerpretation. This capability, therefore, must be obtained in the initial hiring of faculty. The other capabilities to be emphasized will undoubtedly be determined on the basis of the primary applications of interest to the department undertaking this program and the facilities at hand.

FUNDING THE NEW START

Once a decision has been made by a department to develop or significantly expand the teaching of remote sensing the faculty will then be faced with the problem of how to provide funding. In these days of very restricted university budgets and strong competition for research dollars, this is not an easy thing to do. Some possible solutions to this dilemma will be considered in three parts: 1) the funding of new faculty and staff, 2) the purchasing of equipment and 3) the acquisition of teaching materials.

Faculty and Staff

The National Science Foundation and the HEW Office of Education both have grant programs which may be tapped to obtain funding for a new program. One must examine the current description of these grants very carefully to determine the criteria for funding, such that a program may be designed to be consistent with their goals. The Office of Education grants are mostly oriented toward undergraduate programs; whereas, the NSF grants include monies for both undergraduate and graduate education. The remote sensing program at Colorado State University was aided significantly by an NSF education grant.

If funding from an education grant is to be used for a new start or expansion of an existing program, the departments and faculty involved should carefully evaluate the kind of program they are developing and make sure that it meets their long range goals. It is always tempting to modify one's goals to agree with the criteria for a grant, simply to obtain the needed support monies. Eventually, however, the grant monies will disappear and the programs must become self supporting. Careful consideration must be given to the long range source of funds (resident instruction and research), which should be consistent with the long range department and faculty goals, if a healthy and stable program is to be achieved.

There are numerous opportunities whereby NASA and other federal agencies, interested in remote sensing, could help a struggling new program by requiring more direct involvement of the universities in demonstration projects. Most, though not all, demonstration projects with state agencies use NASA personnel and NASA facilities for the processing of remote sensing data. Although some direct NASA or other federal agency involvement is probably necessary for many projects, the opportunities to involve the universities are for the most part overlooked. This could be a very effective way to help fund an expanding education program, while carrying out demonstration projects to interest state agencies in remote sensing. Furthermore, secondary benefits would almost certainly accrue from building closer ties between the state agency and university personnel.

Equipment and Facilities

Probably the best sources for monies to obtain educational equipment are the National Science Foundation equipment grants. These grants require matching funds from the state, so some state support must be available before this source can be tapped. Grants are typically in the $10,000 to $30,000 range, so when matching state funds are added you can obtain a great deal of equipment.

Specialized equipment can also be obtained in conjunction with research projects. This equipment, however, may not be the most desirable for educational purposes. Nevertheless, it is important to have good research equipment on hand to support graduate students and their thesis research programs. In some instances it may be possible to obtain equipment on loan from federal agencies to support specific research projects, but of course, these equipments ultimately must be returned to the funding agencies. This can be very helpful, however, for getting a new graduate research program started.

Teaching Materials

A new program will probably find it particularly difficult to obtain slides for lectures and images for use in laboratory exercises. After several years experience in this field, the faculty member will begin to build up his own sets of slides and images. But in the meantime he needs some packaged sets of materials to get started.

For lecture purposes, the Technology Application Center at New Mexico University has developed several slide-tape cassette programs dealing with remote sensing. These include a basic set governing remote sensing principles and several application tape-slide series. Specifically the series which are available now are: R 100 Remote Sensing, R 200 Food Watch by Satellite, R 300 Prospecting by Satellite, R 400 Hydrology by Satellite, and R 500 Forestry and Remote Sensing. These can be obtained from the Audio-Visual Institute, 6839 Guadalupe Trail NW, Albuquerque, New Mexico, 87107.

Purdue University also has a comprehensive set of slides and audio cassettes covering the principles and applications of remote sensing. There are other organizations as well which have slides and cassette programs available, so lecture materials should be readily available to anyone needing them.

The availability of information for use in laboratories is more restricted. The U. S. Forest Service has recently reprinted their basic photo interpretation kit which concentrates, of course, on forestry applications. These kits include problem sheets, aerial photo protractors, crown diameter scales, a photo alignment guide, a parallax wedge, a slope percent scale, and several dot grids for measuring areas. Several black and white photographs are included for carrying out exercises for each of the thirteen problems included. A training handbook is included which describes the basic techniques in forest photo interpretation. These are good basic materials, but they will have to be supplemented with some color and color infrared photography and satellite imagery, since none of these remote sensing products are included. These basic photo interpretation kits may be obtained from:

U.S. Forest Service
Cartographic Information Office
Engineering
324 25th Street
Federal Building
Ogden, Utah 84401

In 1975, NASA published a document, Photointerpretation Guide for Forest Resource Inventories, JSC-0997. This guide includes color and color infrared photography so it is more up-to-date than the kit obtained from the Forest Service.

The U. S. Geological Survey, EROS Data Center at Sioux Falls, South Dakota has prepared laboratory exercises using aircraft and satellite imagery which cover a variety of applications and could be very easily incorpoated into a laboratory course. The exercises include hydrology, geology, land use and forestry applications, et al, so they provide a broader scope of exercises than do the previous materials described above. If interested, an inquiry relative to availability and cost should be sent to the EROS Data Center.

The Colorado School of Mines of Golden, Colorado offers a Geology/ Remote Sensing laboratory manual with images. This manual and the images concentrate exclusively on geological applications.

The Aerial Discovery Manual, published by John Wiley and Sons, can be used quite effectively in beginning laboratory courses. This manual consists of a basic section on aerial photographic interpretation, plus sections on photogeology and photohydrology. This manual could be particularly helpful for a new program since printed images and maps are included in the manual for use in laboratory exercises.

It should be emphasized that none of the materials described in this section are being recommended over any other sources which may be available. These are the materials of which this author is aware and they are mentioned here only as a service to those who may not have such information.

Anyone who has taught remote sensing knows there is a basic flaw in the use of any of these packaged sets of slides and images. The flaw is the lack of indepth familiarity with the image and the scene it covers. Inevitably students are going to ask questions which the instructor cannot answer. As soon as possible, therefore, the instructor should develop teaching materials from his own research.

Slides can be obtained from research projects at little cost. Hence, lecture materials should not present any problem. Obtaining multiple copies of images for laboratory use, however, can involve a large expense. This presents an opportunity whereby NASA and/or U.S.G.S. could assist faculty in developing teaching materials from research products. The benefits would be many, including more up-to-date courses and more student awareness of the role of research in education.

The Use of Multimedia and Programmed Teaching Machines for Remote Sensing Education

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WHAT ARE WE TALKING ABOUT?

An instructional technologist whimsically suggested an alternative to the title of this presentation: "Remote Sensing Interactive Mechanisms for Pedagogical Enhancement in the Management of the Cognitive Domain."[1/] That may or may not make more sense to you than the given title, depending on your knowledge of the terms used. To get us all on the same wavelength, I think it best to define some terms, even though the experts in instructional technology do not always agree on the definitions of terms.

Terminology

"Instructional technology" is the broad term used to encompass multimedia and teaching machines, just as "remote sensing technology" is used to encompass multiband and multispectral scanners. Instructional technology has been referred to as a new applied behavioral science approach, using scientific methods developed in many of the social and behavioral sciences, to solve the problems of teaching and learning (ref. 1). The technology includes equipment and media resources--the hardware and software--and the process of systematic instructional planning, often referred to as pedagogy. In defense of the jargon used (we likewise use much jargon in remote sensing): many people do belittle the jargon in a new field of endeavor, and it probably does sound cliquish to most of us at times; but if we consider that the American English language is a living language because it is constantly changing and growing, we will not disparage the use of words developed to express some idea or concept. Someday those words will be the standard usage.

Multimedia and teaching machines are only one aspect of instructional technology. Multimedia means the sequential use of a variety of instructional materials for presentation or for self-study programs. Media include all printed, mechanical, and electronic forms of communication, anything that is a carrier of communication (ref. 2). The teaching machine is, in essence, any machine which supposedly teaches. (The teacher, if you consider a human being a biological machine, is also a teaching machine--the original teaching machine.) Yet, if we are more concerned about the goal of education--of having the student acquire knowledge, we should be talking about learning. The so-called teaching machine might preferably then be any machine which helps the student to learn. Media are inherently a part of teaching machines.

Scope

Now that we have defined the basic terms, I think you can see where the scope of this paper might lead us. Given that one instructional technologist has already predicted the demise of the teaching machine and given that you are probably tired of hearing anything about another "multi" then our introduction becomes the scope of the paper, if we were to leave it at that. But I believe we must expand on our title and talk about instructional technology, not only about the media/machine component, but also about the systematic way of designing, applying and evaluating the total process of teaching and learning.

TEACHERS NEED TO LEARN

As teachers (i.e., those who facilitate learning for the student) we need to have some knowledge of the functioning of the learning process--we need to learn how to teach. Many teachers are either resentful of the new instructional technology methods or are reluctant to use them because of their own unfamiliarity. Many of us have those feelings, just as many others have those same feelings about remote sensing technology, partially because remote sensing is a new field which has been oversold at times. Eventually there will be many desirable results from both instructional technology and remote sensing technology, after the proper research has been conducted, practical uses properly demonstrated, and results properly communicated to the users.

As teachers we must be aware of what we are trying to accomplish and must ask ourselves a couple of questions: Are we trying to determine which students are more capable and who therefore will get the A, B, C, D, and F, or are we trying to transmit ideas so others can learn to be better, more creative persons? It seems to me that the goal of most universities is toward the latter and therefore we should at least be striving toward that goal even though we must compromise at times to satisfy our human limitations. We all realize that there is a tradeoff here between ideals and time and resources.

WHAT TEACHERS NEED TO KNOW

In their book "Instructional Technology: Its Nature and Use," Wittich and Schuller (ref. 1) point out some basic generalizations and guiding principles of learning and when media become appropriate:

1. "Effective learning begins with firsthand or concrete experiences and proceeds toward more abstract experiences. Thus a

student who has the advantage of reacting to well-selected and wisely used media and materials can learn more effectively than one who is provided with largely verbal information and materials.

2. A learner profits most from instruction when he becomes involved through his own interests and desires. Well-chosen educational media present concepts in such a way as to incite interest and stimulate involvement.

3. A student who is knowledgeable and whose interests are aroused is better able to perform as a creative, inventive human being.

4. The most objective evidence that a learner has accomplished his goal is to be found as one observes and evaluates the quality of the responses he makes to instruction. Observable behaviors shown by learners after they have responded to media instructional opportunities present tangible evidence that can be measured, evaluated, and used by teachers as the basis for continual replanning and improvement."

A THEORY OF LEARNING

There are many theories on how students learn and one of the most intriguing, especially for remote sensing specialists, appeared in the Journal Phi Delta Kappan, February 1978 (ref. 3).

The author of that article believes that schools are largely brain-antagonistic in the sense that the process of learning depends not upon what the teacher has presented in class but more so on the total, previously stored experience of a particular brain. Neuroscientists generally agree that the brain works by programs, not in a logical step-by-step manner, but by processing slowly along many sequences at once and by perceiving patterns. Proster theory defines learning as the acquisition of useful programs which are stored in the brain in structures or "prosters." These "prosters" are found by pattern detection and the best way to enhance learning is to provide great amounts of input.

Hart believes media can provide the mechanism for providing great amounts of raw material to the student, but the media or teaching machines must be properly programmed and he points out why: "The teaching machine, the great failure of recent years, was not oriented to build useful programs but instead focused only on right answers. Other audiovisual devices, too, ask for right answers rather than guide correct program building..."

As Amron Katz says, "gadgets are necessary but insufficient," (ref. 4). It takes people to program machines, and in both educational technology and remote sensing technology, the hardware is more advanced than the software, just as technology in general is ahead of mankind's ability to cope with it. In fact, Wittich and Schuller (ref. 1) commit the very sin they are attempting to dispel by continuing the myth and promoting the fears of people who believe the machine is becoming human. They state that "media have proved beyond all doubt their ability to communicate appropriate content information with efficiency." In this respect we had better be careful--for we may someday yet get to the point of building that computer which occupies 9 square blocks and is 10,000 times more advanced than the ILLIAC computer. And scientists will marvel over this device and ask the one question most on their minds, "Is there a God?," and feed it to the computer. And the computer will spit back the answer, "There is one now!"

In the planning and execution of learning strategies we might take the suggestion of Carpenter (ref. 5), who gives these practical guidelines:

1. Provide a variety of conditions for learning, including size and composition of the learning group, the schedule and depth of material.

2. Simulate conditions which the student may encounter in his future learning situations.

3. Train students in the strategies and skills for learning under the special conditions (like individualized learning) provided for formal learning.

4. Train students to learn to be autonomous learners.

THE GOOD AND THE BAD OF INSTRUCTIONAL TECHNOLOGY

Advantages

It has been shown in many studies that students can learn effectively with new instructional technology methods and media. Some of the reasons for this are:

1. A greater variety of methods and messages are possible. This can reinforce learning.

2. A greater variety may motivate some students who may not otherwise have been inspired.

3. Students can get more involved in the learning process.

4. It may help to improve the teacher because the use of instructional technology requires more exacting work.

5. It can bring renowned instructors into the program through the use of audiovisual aids.

6. It can keep material current with audiovisual aids.

7. Teachers can reach a greater audience.

8. More responsibility to learn is put on the student where it belongs.

Limitations

There are also possible drawbacks in the use of instructional technology that we should be aware of:

1. As instructors we may seem to lose personal contact with the students.

2. Some students may lose motivation because of the loss of personal contact; some may not take the responsibility to learn.

3. Costs may be high for equipment, materials, and programming.

4. Much planning is necessary.

5. If instructors tie themselves too closely to the use of media and teaching machines they may lose flexibility.

6. We cannot assume a student has learned once he has viewed a slide/tape program. There must be a change in behavior, and feedback.

7. Media may not be appropriate for some topics.

Warnings

There are some who warn us to be wary of individualized or programmed instruction. Charles F. Hoban (ref. 6) believes that some of the ideas which have come from psychologist B. F. Skinner's philosophy, especially programmed instruction, individually prescribed instruction and educational objectives in behavioral terms of performance, can be antisocial because of a lack of engagement in group or team activity and interaction, and in community involvement. Hoban is not saying there is no place for these concepts of education but that they cannot be relied on totally, partly because there has not been thorough research on the long-term results of such education. Likewise, hardware cannot be relied on totally to accomplish the education task, but rather "the development and promulgation of understanding and application of the systems concept." (We must realize that the types of instruction promoted by Skinner need not be on an individual basis but can be done also on a group basis).

Others warn that we are becoming machine-dependent, that we are prouder of our machines than of our people or of the products of our machines. Take for example a remote sensing specialist showing off his new half-million-dollar image processing machine which has, as yet, shown no useful results. But machines do have their place, and we could if we wanted, put our creative human energy to better use if we employed machines to do tasks more suited to them. Multimedia and teaching machines are expedient to handle large numbers, and if we really want to teach and have students learn, then we should take advantage of machines: use them as aids so we can better use our talents to teach.

Learn from History

Instructional technology and all it implies can be used effectively and will not necessarily be the demise of education--just as the ability to write did not mean the demise of truth as Socrates suggested to Phaedrus about the newly acquired ability to write: "for this discovery of yours will create forgetfulness in the learners' soul, because they will not use their memories; they will trust to the external written characters and not remember for themselves. The specific which you have discovered is an aid not to memory, but to reminiscence, and you give your disciples not truth, but only the semblance of truth; they will be hearers of many things and will have learned nothing" (ref. 7).

The purpose of planned education is to motivate and teach many people at an advanced rate to learn how to learn and to be creative, productive human beings. Otherwise, people could learn on their own, in their own way and in their own time. Media can assist to help motivate and teach at a rate faster than the daily trial and error learning experience. Strome and Lauer (ref. 8), in discussing the efforts being made to shorten the time to transfer technology, point out that media are a principal means for motivating and communicating with others in this educational process.

Disappointments

Some instructors never did believe in the new instructional technology and many others have been disappointed by the results thus far generated. Gillett (ref. 2) lists some of the basic causes for this:

1. The most pervasive cause is the lack of understanding about the process of human learning. One result of this is the selection of inappropriate mediums for a particular message.

2. Lack of sufficient funds.

3. Significant change, as promoted by instructional technology, is not possible in an educational process which is basically conservative.

4. Because of such fears as "machines replace teachers in the classroom," there is much indifference or antipathy toward the use of technology.

5. Many programs that have been developed for instructional technology have been poor and therefore do not sell.

6. Much equipment is poorly designed and obsolescent. Hardware and software are not always compatible between brands.

7. Both hardware and software may not be easy to get. They may have to be scheduled months ahead of time and at inappropriate times during a course. The process of getting an item may be more trouble than it's worth.

8. Most instructors have not been trained to use instructional technology and are therefore not aware of its capabilities and generally reluctant to use something new.

9. Media specialists have not been included in curriculum development.

DeBernardis (ref. 9) bluntly states that very little media have been integrated into the teaching and learning process. Meierhenry (ref. 10) looking at the role of media in the future of higher education, noted that educational technology is most prevalent in engineering, computers and applied health fields, in community and technical colleges, in nontraditional types of education like open universities, and in the military. Meierhenry does not explain why this is so; some of these areas are oriented more toward the training (what many might call the Skinnerian) approach rather than the educational approach to learning, and this might help to explain why certain fields and institutions would use educational technology. Educational technology is most advanced in situations where there is heavy emphasis on producing a change in behavior that can be measured; where obtaining knowledge is crucial to the success of the learner and the enterprise.

PURPOSE OF MEDIA

One of the disappointments of media is the inability of many to use the appropriate media to accomplish given goals. As instructors we should be aware of what can be accomplished using different instructional techniques. The rationale for choosing instructional media rests on the assumptions that educational objectives require different kinds of learning and that media are vehicles for providing different stimulus presentations (ref. 11). Gerlach and Ely (ref. 12) discuss teaching and media in great detail in this respect and McKeachie and Kimble (ref. 13) specify the appropriate goal for given media techniques. These are listed in Appendix A and are a good starting point for any instructor.

HOW MUCH DOES IT COST?

One of the best studies done on the cost of instruction in relation to achievement was by Brooks and Leth (ref. 14). They surveyed 64 colleges and universities with large multi-sectional communications courses. The following taxonomy was used to define the instruction method and the number in parenthesis identifies the percentage of schools in the survey using this method.

1. Computer-managed (CMI) or computer-assisted instruction (CAI) (3%).
2. Self-instruction (programmed learning, auto-tutorial, individualized learning, directed study, audio or video cassette packages) (11%).
3. Mass lecture (televised, in person, or multi-media) (40%).
4. Simulation and/or games (11%).
5. Use of peers, other undergrads having completed the course or other paraprofessionals (13%).
6. Instructional radio or TV (9%).
7. Course credit by exam or prior experience (40%).

The authors noted that mass lecture was the most often used but also the type of instructional method most discarded because: it was too costly; had lower achievement; there was student apathy and instructor and student negative attitudes; instructors were constantly redoing materials; there was little or no interaction; and there were problems with equipment. The survey indicated that except for instructional radio and television and credit by exam, achievement for non-traditional methods is as high as for traditional methods.

Brooks and Leth's survey also developed some of the best cost estimates of different types of instruction. These are listed in table 1.

Self-instruction module learning was found to be more efficient and student evaluations higher than traditional methods because:

1. The emphasis is on the student's learning rather than the teacher telling.

2. There is repetition in the module methods.

3. Module learning, which has small segments of material logically sequenced and "built-in" self correction, is effective in itself.

4. Students get involved in the learning process.

5. The student can progress at his own rate.

Instructors were quite satisfied with the modules also and they found that students participated in class more than ever before.

Edward Caffarella (ref. 15), after reviewing the literature of cost studies, developed a number of propositions on the cost effectiveness of media. Three of the more pertinent ones are:

1. The costs of instructional media technology vary with the level of sophistication of the production.

2. The use of instructional media technology can result in savings in student learning time.

3. Educational institutions can increase their student/faculty ratio through the use of instructional media technology.

Tickton (ref. 17, pp 992-997, 1012-1013) also lists a number of good economic evaluations of instructional media.

WHERE ARE WE TODAY

College-wide Programs

Many innovative instructional technology programs have been developed throughout the country, mainly in smaller private and community colleges. Some of the more renowned programs, described in references 1 and 16, are:

1. A Personalized Education Program at Oakland Community College, Michigan which matches the cognitive style of the student with the methods and media by which he learns.

2. A college-wide Audio-Visual Tutorial Program at Lansing Community College, Michigan.

3. A DATA GRAM system at Oklahoma Christian College in Oklahoma uses a dial-access system for individual or group listening to tapes. There were 120 dial access information retrieval systems in the United States in 1970 (ref. 17).

4. Gillett (ref. 2) lists a number of new developments in Canada and internationally, including one which has been described as a "learning cafeteria." The Cross-Cultural Learning Center of the University of Western Ontario uses multimedia, computer-assisted information system using films, slides and sound shows, books, videotapes, music and artifacts to orient Canadians before they go to work in less developed countries.

5. Portland Community College in the last two years has developed a shopping center approach to education which is time independent. Students shop in a center for the curriculum and courses they wish to take and select a program after counsel with the college staff. The individual courses are programmed instruction packages using various media. One other unique feature of the college is that every student graduating is guaranteed job placement.

These are but a few of the more illustrious programs that have developed on a college-wide basis in the last 15-20 years. In remote sensing we may not be able to relate to these directly but we can relate to the following individual programs or developments.

Optical Videodisc

One of the most significant technological developments in recent years, especially with respect to both remote sensing and instructional technology, is the optical videodisc. As explained by E. M. (Mac) Gardiner,[2/] the videodisc is a 12" diameter disc much like a phonograph record which provides for storage and retrieval of audiovisual as well as alphanumeric and computer information. With an optical pickup, a user has the capability to retrieve any of the following: (1) 30 minutes of full color or black and white high resolution motion picture with sound, or video with sound, on one side of a disc; (2) 54,000 separate, individual high resolution frames of full color image; (3) 200 hours of audio output; or (4) 54 billion bits of alphanumeric or computer information. The above information can be mixed on the videodisc so that a user can obtain any combination of motion, aural, video and single frame information in any sequence.

As described by one of the leading companies in the field, the videodisc is accessed by an optical contact, low power, helium-neon laser beam of coherent light in a compact portable player and the image is displayed on any standard TV receiver, monitor or CRT device. Information from audiovisual and many other sources can be mastered, replicated, and distributed on these discs. Because the information which is contained on them is retrieved without contact, there is a transparent plastic layer to protect the surface which makes them more durable than phonodiscs. Any of the disc's 54,000 indexed frames can be accessed immediately using a digital readout controller.

It appears that the videodisc is a very powerful tool for storing and retrieving vast volumes of information in any format on media quickly, easily and economically. One version, the MCA DISCO-VISION industrial player was designed for instruction, training, audiovisual archive file retrieval and other communications uses. MCA is also putting out a consumer unit which is reported to cost approximately $600.

The potential uses of the videodisc are numerous but some of the more immediate applications that come to mind are:

1. An entire curriculum of course audiovisual material could be stored on one videodisc for student self-programming. Used in conjunction with a computer, any course could be accessed by a student using any media--video, movies, stills, sound, etc. With any computer software programs employing a branching and subroutine capability, a student could be tutored through a course.

2. All forms of information could be put on videodisc for storage and quick access in libraries. For example, all the pages of the Encyclopedia Britannica and all its supplements could be stored on one videodisc with room to spare.

3. Entire courses can be put on the videodisc for mailing to correspondence and extension course people around the country and to provide education modules for those in less developed countries.

4. The use of videodiscs for storing and immediate retrieval of aerial photographs, LANDSAT scenes, and other imagery is a most timely innovation.

Think of the potential of using a computer-controlled videodisc to project a holographic or other stereo image on a screen for a student to view, interpret, and answer questions about. That sounds intriguing for management and research also. Or consider how it could aid an instructor to answer a student's question he doesn't know the answer to, if he were to have a terminal and CRT in front of him in the classroom.

To expand on the computer-controlled videodisc, Alan Kelloch, Vice President, McGraw-Hill Book Company (ref. 18) forecasted the use of the videodisc with TICCIT (Time-Shared, Interactive, Computer-Controlled Information Television) a system which now combines computer and television technologies with instructional technology. The TICCIT approach is one of individualized interactive instruction in which the machine and software technology act as a tutor and essentially fulfills the role of: (1) identifying the student's needs; (2) describing and evaluating options for the student; (3) establishing goals and objectives with the student; (4) organizing learning content and structure; and, (5) orienting the student on procedures. The advantage of using videodisc with TICCIT is the high storage and ready access capacity of videodisc so that there is a very high degree of interaction by the students, almost as if he had his own personal tutor available to him when needed.

The optical videodisc has much potential for us both in remote sensing teaching and research. Being a new technology, it will be up to us to search it out and find those potentialities and apply them to our needs.

Audio-Tutorial Approaches

The Origin

The audio-tutorial approach to education was developed by S. N. Postlethwait at Purdue University in 1961 (ref. 19). It is one of the most widely used multimedia and self-instruction approaches to learning in the world today. It also seems to be the most widely used new approach in remote sensing education, having known proponents at Purdue, Minnesota, Oregon State, and Idaho. The author became acquainted with this system through Professor H. J. Arneman, of the Soil Science Department, University of Minnesota who had studied Professor Postlethwait's development at Purdue and established his own for a basic soils course.

Minnesota and Idaho Systems

Through the aid of educational development and equipment grants at the University of Minnesota, the author was able to obtain in 1971 the necessary audio and visual equipment to establish a similar program for his aerial photo interpretation course. The production of program materials, slides and tape for the first year was not an easy task, and the time spent by just this author approximated 400 hours. The cost of the equipment, materials and production was about $6000.

Synchronized slide/tape programs were developed for 12 laboratory exercises with an accompanying lab handout detailing objectives, references, the problem and expected results. The audio-tutorial programs were available in the aerial photo interpretation lab, in the library and at the Learning Resources Center of the St. Paul campus. Most carrels included reel-to-reel tape recorders, carousel slide projectors and a rear view screen. A teaching assistant was available in the aerial photo interpretation lab for 20 hours per week and the instructor visited the lab often during the first year.

The course was taught by the author once a year for three years at the University of Minnesota and when transferred to the University of Idaho, the audio tutorial approach was again established and taught twice a year. Since 1972 it has been taught 10 times with approximately 1100 students taking the course.

Generally the students prefer the audio-tutorial approach because it results in more efficient use of their time. It also provides the student with more opportunity to get assistance in learning procedures and completing exercises. In a structured lab situation the student is confined to two to four hours of lab time and competes with up to 40 other students for the instructor's time. With the audio tutorial approach the student has up to 60 hours within which to review synchronized slide-tape programs or get assistance from a teaching assistant or the instructor. The convenience in planning study time and the ability to move at one's own pace was a great advantage for the range of student abilities.

Some of the other advantages noted for the audiotutorial approach are:

1. The method provides a means for handling higher enrollments more economically.

2. The information passed on to the student through the slide tape programs is standardized for all students.

3. There is potentially more opportunity for student-teacher contact.

4. The instructor can, through the slide-tape programs, get simple ideas across quickly, giving more time to study the more abstract ideas and concepts.

Two trends that have been apparent throughout the last six years in this course relate to the student, his ability and personality. One is that the more intelligent students who are at the same time independent minded, finish lab exercises very quickly with very few demands on the teaching assistant or instructor, whereas the less intelligent and dependent types must be led by the hand and demand much more of the teaching assistant and instructor than would be required during a structured lab. Like college entrance exams, which greatly favor those who can read and write, any educational process favors those who have the background to proceed to learn. The large group of students between the most and least intelligent and independent required about the same amount of time to do their exercises in the audio-visual compared to the structured lab, but they did it at their own pace.

The other trend that has been apparent is that students' past method of learning, which has usually relied on traditional teacher/lecture approaches, is very difficult to overcome. Students become very dependent on this method after 12 years of school and it is an overwhelming burden for many to have the freedom and responsibility to educate themselves. Nord (ref. 20) noted that in one study, some students rejected self-instruction because they had become followers and were looking for men to teach and grade them rather than media. When using self-instruction techniques students are competing with their own past performance rather than with other students, and they are not used to doing this.

The above trends point out the continuing need to provide many alternatives to the teaching/learning approaches used in education. One approach may be more economical but it is not necessarily the best means of educating people, even those with equal abilities, similar backgrounds and personalities. Because of the demand by many students, this author has instituted a structured lab into his aerial photo interpretation course. The students taking this structured lab seem very interested in the subject material and very conscientious in learning the material. They generally do no better nor worse than the students taking the audio-tutorial approach.

One other thought that I must relate is a personal one in comparing the traditional versus the nontraditional approach to teaching. There is a feeling of loss of control over the teaching/learning situation, a loss of immediate knowledge of how the student is really doing and a loss of contact with many of the students, especially the better students who quickly learn the subject material on their own and need no contact with the instructor. When asked to evaluate a student performance, impersonal lab reports and exams are the only medium.

Oregon State's System

Dave Paine at Oregon State University's School of Forestry has also given an audio-tutorial course in aerial photo interpretation for a number of years, but his is based on the unit mastery model (ref. 21) whereby mastery is demonstrated by completion of examinations before proceeding on to the next subject. Paine generally found the following, as shown by other research on the personalized self-instruction method:

1. Increased mastery and longer retention of material compared to traditional methods.

2. Higher grades, with very few failing.

3. More motivated students and greater student satisfaction.

4. More material covered in the same amount of time.

Paine noted that there were more students who withdrew or dropped from this type of course, some because they could not master the material, others because the material is more difficult and others because they could not discipline themselves to keep pace. Many students (up to 20%) also withdrew from my audio-tutorial course, mainly for the latter reason of the above three. Ninety percent of the students who withdrew told me they just did not do the labs because no one forced them to!

Back to Purdue

Purdue University also uses the audio-tutuorial approach in their remote sensing courses (ref. 22, 23, 24). They have produced professional material to be used in regular courses, continuing education workshops and short courses. The learning modules are explained in "Matrix of Educational and Training Materials in Remote Sensing" (ref. 23) and are for sale to the general community, in contrast to the other audio-tutorial systems mentioned.

USE OF COMPUTERS IN INSTRUCTION

CMI and CAI

Computers are used to both manage and aid instruction. In managing instruction the computer assumes the role of advisor, determining the student's needs, suggesting courses of action, and keeping track of the student's progress. This can provide the student his own personalized program and at the same time eliminate some of the more taxing details for the instructor. It can also keep him up to date. Such a system though requires considerable organization, specification, sequencing and programming of course material. CMI may be used alone or in conjunction with computer-assisted instruction.

Computer-assisted instruction (CAI) takes a more active role in the education of the student by presenting information, asking questions, judging the student's response, and correcting wrong answers--in other words interacting with the student just as an instructor might do. The hope for CAI is to individualize and personalize the instructional process and to simulate experiences that would not otherwise be possible.

The computer could be of any size; size controls the number of students interacting simultaneously. The student communicates with the computer through an Input/Output (I/O) device, usually a terminal of one of the following types: (1) hardcopy output with keyboard input (e.g. teletype); (2) line oriented CRT display with keyboard input; and (3) raster scan graphic display (either black and white or color) with keyboard input. Special I/O devices may supplement the basic terminal. Such input devices include those used to position a cursor or to use a light pen, touch panel or joystick on a CRT display. Special output devices include computer-controlled audiovisual machines or videodisc displays. A digitizer is an example of an I/O device commonly used in remote sensing.

There are a number of dialog types between student and the computer system. The simplest is drill and practice in which the computer asks the student questions, judges and criticizes the answers, and determines the difficulty and subject material for future questions. Another type of dialog is inquiry dialog in which the student asks questions of the system and the system responds after searching and finding an answer. Opposed to the inquiry dialog is a Socratic dialog in which the system asks a series of carefully planned questions of the student, each dependent on the student's previous answer, encouraging the student to learn by himself the desired results. A final type of dialog is simulation dialog in which the system simulates the effects of a student's choice of parameters on the final outcome of a process.

As far as is known there are no uses of CAI in remote sensing education. Most dialogs could be used in teaching remote sensing although some are better suited. The mathematical and statistical aspects of remote sensing and statistics are appropriate for the drill and practice dialog and tasks such as clustering and classification of images would be most adaptable to the simulation dialog.

PLATO and TICCIT

The two most prominent CAI systems developed and currently in use are PLATO (Programmed Logic for Automatic Teaching Operations) and TICCIT (Time-shared, Interactive, Computer-Controlled, Information Television). PLATO was developed in the early 1960's at the University of Illinois and is now the largest computer system designed for education, with 1000 terminals in the United States and overseas connected to a Control Data Corporation Cyber 73-24 computer in Urbana, Illinois (ref. 25). The PLATO system takes advantage of the capabilities of computers to both manage and assist in instruction and utilizes many of the dialogs available. By means of a plasma panel, dynamic graphics can be presented to the student to illustrate principles and concepts to be learned. Professor Ron Danielson, who related much of the CMI and CAI information to me, did his thesis work on the PLATO system.

The other major CAI system which goes by the acronym TICCIT combines computer and television technology with instructional technology. It was developed by a team from the University of Texas, Brigham Young University and MITRE Corporation in the early 1970's. With TICCIT, students use electronic keyboards with color television receivers to interact with the system. The student controls his own instruction, both subject matter and pace at which to work. Lessons for this system were designed by teams of specialists aimed at providing a complete and independent alternative to entire college courses. TICCIT has been installed at Phoenix College, Arizona, Northern Virginia Community College, Virginia and Brigham Young University, Utah.

CAI at Stanford

Although it did not have an acronym (and therefore did not become as well known), CAI systems were developed here at Stanford under the direction of Patrick Suppes of the Institute for Mathematical Studies in the Social Sciences in the early 1960's and the CAI instruction was used in grade schools in 1965 and at the university level in 1967. From this early work, CAI systems are now available through Computer Curriculum Corporation (CCC); these consist of an instructional computer which can provide individualized instruction to as many as 96 CRT or teletype terminals simultaneously (ref. 26). CCC offers a variety of courses for elementary through junior college students and they have installed several thousand terminals throughout the United States.

ITC Multiscan

The International Institute for Aerial Survey and Earth Sciences (ITC) uses multimedia in teaching their many courses according to Mr. John Richardson, Head of the Centre for the Advancement of Learning and Teaching at ITC. Audio tape/slide/instruction booklets have been developed in cooperation with Shirley M. Davis, Education and Training Specialist, at LARS, Purdue University. These programs are used to teach applications of remote sensing in soil, geologic and rural surveys. ITC instructors also employ the use of stereo projected images.

ITC is in the process of developing a teaching machine to be used for instruction in aerial photo interpretation by more than two persons simultaneously. According to Mr. E. Bergsma, Coordinator of the Project, the principle of the machine is proprietary information at this time but it appears that it has potential use for them in their courses and they are discussing the production of it.

The instrument is called Multiscan (another multi) and allows a number of participants to study the same pair of aerial photographs stereoscopically and to see any delineation of lines or annotations made by any of the other participants. This technique has great potential for small group student discussion or for demonstration and instruction to student groups. For example, in small group discussions, five students and an instructor may be interpreting vegetation types before going to the field. They sit at their individual tables discussing the boundary lines to be drawn around homogeneous types. One student draws in a polygon which all other students and the instructor readily see and can make a judgement on. They then critique the interpretation and draw in alternate lines if they differ.

This is an advancement in the training of students in aerial photo interpretation, since up to this time only two persons could study the same stereopair and reference positions within the 3-D model. This is now accomplished using a dual Old Delft Scanning Stereoscope, a Condor T-ZZY Dual Stereoscope or a Lietz Double-Reflecting Stereoscope, all instruments of which are generally available.

Other Possibilities

Other developments which might affect instructional technology are: holography, which could make possible many 3-D forms of media; lasers which could provide greater amounts and rates of data transmission; and, microform which could, in the not too distant future, store 20,000 volumes on an 8" x 10" sheet (ref. 27).

Miller (ref. 28) and Beckwith (ref. 27) also note the needs or hopes for other new products:

1. An inexpensive automated carrel which contains audio and visual terminals to computers, and a light pen with CRT.

2. A portable microfilm reader.

3. An automated carrel in a briefcase which contains a TV screen, light pen, micro-optical information storage file, remote TV camera and tripod, teletype keyboard, touchtone keyboard and telephone.

4. Optical print reader which could read many fonts of type from books and digitally store the entire book on computer.

5. On-line electronic blackboard which enlarges displays of a computer output.

6. Home cartridge video-tape player and recorder.

7. High quality copying at $.01 per page or less in black and white or color.

8. Large screen TV displays.

9. Combination TV and motion picture projectors.

10. Long lasting inexpensive battery powered TV receivers.

11. Rapid inexpensive copying of video tapes.

12. Small, battery operated, two way telephones.

13. Use of microfilm technology to provide random access, large capacity slide projections.

14. TV screens which can retain an image without regenerating the signal.

TRENDS IN INSTRUCTIONAL TECHNOLOGY

Gerald Brong, Instructional Technologist at Washington State University, related to me recently some of the trends in Instructional Technology.

1. He believed we were going back to time-dependence education in order to get the interaction of students with students. In such education the students would meet a minimum core curriculum which is evaluated by instructors.

2. There is a trend toward more software packages used by the universities.

3. There is generally better access to audio and visual media.

4. Instructional design systems and audiovisual equipment are becoming more centralized.

5. At many universities, semi-official faculty groups have organized with the purpose of improving instruction.

6. The trend in materials is toward 35mm slides and sound, especially 35mm projectors, tape recorders, and also 16mm film. Approximately $730 million was spent in 1976 on 2" x 2" slides in the United States and slides are one of the fastest growing media today according to Hope Reports, Sept. 1977.

ADVANTAGES, LIMITATIONS AND USES OF MEDIA-AIDED TEACHING

I would like to briefly discuss the advantages, limitations, and uses of the devices we use to aid in teaching and learning. Most of us are familiar with those devices we generally call audiovisual aids, but have we really taken the opportunity to learn when to and when not to use them, and how to use them properly. Much information is available on these media, some of the better texts are references 1, 12, 29, 30, and 31. A list of various media materials and equipment is given in Appendix B and sources for these are included in Appendix C.

There was insufficient time to survey the entire remote sensing community to determine the extent of use of media-aided teaching. The questionnaire handed out during this conference should enlighten us more.

Overhead Projectors and Transparencies

Advantages

The overhead with transparencies is a very simple device to operate and the instructor can maintain contact and rapport with both large and small groups. It is much easier to write on transparency material than on the blackboard and in contrast to slides, appropriate material can be prepared in a very short time at short notice. The overhead can also be used well in a lighted room.

Limitations

There are no major limitations of the overhead projector, only minor problem areas which the instructor, being aware of, can easily overcome. Some of these are: proper positioning of the projector, availability of the projector when needed, and over-reliance on the projector and materials presented with it.

Uses

Loy (ref. 32) reported on the use of glass diapositives with an overhead projector for use in geography classes. Of course any transparent image can be used, and this is especially appropriate to remote sensing where we may have many such images--U-2, LANDSAT, CIR resource images--to discuss in a classroom or individual group situation.

One other use of the overhead dawned on me just recently while preparing this paper. I have worked with 35mm stereo projection systems for ten years and have always had to make 35mm slides of the larger format 305 x 305mm (9 x 9-inch) transparency or opaque in order to project it to an entire class in stereo. Why not use two overhead projectors with polarized filters instead of 35mm projectors for large format transparencies? So I attempted it, and it worked! --not without some difficulty though. The lenses of the projectors must be matched; the projectors should be put as close to one another as possible, parallel and projecting the image perpendicular to the screen without keystoning; and the images need to be masked to subdue all superfluous light. It takes some patience to register the images, as any movement in one direction of the image on the projector causes a reverse movement on the screen. With polarized filters on the projector lenses oriented at 90° from one another and viewing with complimentary filtered polarized glasses the 3-D image is marvelous. A viewer can stand within inches of the screen if necessary to study the scene. This has potential for further development.

35mm and Lantern Projectors and Slides

Advantages

Pictures are a powerful tool in learning and can truly say more than a thousand words. They are very good for visual identification. Projectors and slides are relatively inexpensive, especially 35mm, and are generally available. They can be used in small or large group situations. They can be combined in multiples and used with many other media.

Limitations

Probably the greatest disadvantage to slides is over-reliance on them in a classroom situation because they are good "fillers" and "attention getters." This media also requires a darkened room in many cases, and therefore precludes the taking of notes, either because it is dark or because the student is asleep. Finally, slides are not the best medium for developing desirable attitudes or opinions, as shown by some studies.

Uses

The slide has one of the highest uses of any medium in remote sensing. Since the camera system is a remote sensor, the use of images taken by this system is natural for presentation and discussion and I would venture to say it is used extensively in every remote sensing course taught.

The slide and projector are commonly used both in the classroom-lecture situation and in the multimedia, self-instruction situation. One of the most useful techniques involving the slide is in a 3-D mode. This involves simply the use of two projectors, a polarized or anaglyphic filtering system and a silver lenticular screen. Such systems are described in most photogrammetry texts and also in an article by Kiefer (ref. 33). Ralph Kiefer related to me that he has had more requests for his article on "Classroom 3-D Projection of Landform Photography" than most of his other published articles and that many requests are coming from foreign countries and the medical and dental fields.

The slides for a 3-D system are relatively easy to take, either of an original scene or of existing aerial stereopair. Professor William Hall of the University of Idaho has been working on a color oblique stereo aerial photo (COSA) system for over 20 years. He has published a guide to the making of these photographs (ref. 34) and has developed a motorized 3-D projector platform. Professor Hall has developed one for us in the College of Forestry, one for the EROS Data Center and others.

One of the earliest 3-D projector stands was developed by Professor Kenneth Jackson in about 1952 and is listed as one of the training aid devices by Colcord (ref. 35). I used the Jackson stereoviewing device in about 1969 at the University of Minnesota for a basic course in aerial photo interpretation. It was especially valuable for introducing stereoscopy to the students. Jackson's model, at that time, did not have motorized drive for X, Y and θ motions but that may not be an absolute necessity.

Tape Recorders and Recordings

Advantages

Tape recorders and recorded tapes are relatively cheap, easy to use and readily available. They offer the opportunity to be in two places at once, to record significant events for future use and to bring in guest lecturers, at least their voices. One of the best advantages, often overlooked, is the use of the tape as a diagnostic tool for helping to improve one's speech. Speech compression, another advantageous feature of audio tapes, is often overlooked, yet we could all use it, except possibly for Bob Colwell.

Limitations

The tape recorder is a little more complicated than an overhead or 35-mm projector and the untrained operator can damage either the machine or the tape recording. Many students find it difficult to listen to a tape by itself and more than often desire a visual presentation to go with it. Locating specific points or places on a tape can be frustrating.

Uses

The use of tapes in remote sensing are mainly in conjunction with slides for self-paced, self-instruction programs. Tapes are used in the programs developed at Idaho, Minnesota, Oregon, Purdue, EDC, and the Technology Applications Center.

Motion Picture Film Projectors and Films

Advantages

Motion pictures can accurately capture the visual scene for later presentation and are especially good for depicting important events. They can provide more relevance for the student if the film displays real life events or on-the-job scenes. The film, especially with sound, can extend the classroom situation and take a student, for example, on a remote sensing aerial mission. Films can be easily integrated into most courses and if properly scheduled can provide a motivating and learning experience for the students. It has been calculated that the retention rates for different channels of information are: reading - 10%; hearing - 18%; seeing - 25%; and seeing and hearing 48% (Gillett 1973), which would indicate that films, television and multimedia would have advantage in this respect.

Limitations

Motion picture films are expensive to produce. Because of this a limited number are produced in any one field by a certain group or producer of films. As much as the producer may try, he cannot make the film applicable to every situation and therefore many instructors do not use films because they feel a particular film is not appropriate for their situation. Unless the film topic covers very basic subject matter, the film soon becomes outdated.

Other problems with motion picture films relates to their use by the instructor. They can be expensive to use if the instructor must purchase or rent the film, using his limited budget to do so. In presenting the film, the instructor may run into more problems than with other media: the film and projector may be difficult to schedule, the projector may be a nuisance to set up and it is a little more complicated to operate than an overhead or slide projector. The film should also be previewed by the instructor, which takes time, and an appropriate lesson plan or question/answer sheet prepared to aid the student in learning. The film can, and many times is, used to fill time.

Uses

The motion picture film medium is used in many courses in remote sensing and there are a limited number of films specifically on remote sensing available. The EROS Data Center has the greatest number of such films on the subject. Known film suppliers are listed under sources. Colcord (ref. 35) lists other sources prior to 1968, especially for films on photogrammetry.

Educational and Instructional Television

Advantages

Many of the advantages of the other media mentioned apply to television. In addition, television can reach larger groups of people than even motion picture films. Live (real time) television can provide an immediacy which no other media can. Television can bring to the student many experts and instructors who would not otherwise be available.

Limitations

As with the advantages, the limitations of many other media also apply to television. In addition small TV screens can be a hindrance to large audience viewing and the resolution capabilities of TV may be less than other media. Educational and instructonal TV is usually limited (at this time) to black and white, whereas the other media generally use color. TV, maybe more so than other media because of its familiarity, can promote passivity in the student and the active interaction of learning is lost.

Uses

Closed circuit educational TV (CCTV) is very common in colleges and universities around the country. As far as is known there are no remote sensing courses taught strictly by CCTV. Television though is used to aid in the instruction of courses, and in one case to present an entire course. Dallas County Community College has developed a credit remote sensing shortcourse called "Earth, Sea, and Sky" which utilizes video tapes and a workbook. Purdue uses video in their programs and, according to Mike Inglis, the Technology Applications Center is investigating the possibility of using TV. Colorado State videotapes its photogrammetry classes.

The EROS Data Center recently gained the capability of viewing their image processing monitors (Image 100, IDIMS, ISI 170) from a classroom situation. The video signal is picked up directly from a particular monitor, converted to a composite signal in color and sent by video cable to a classroom 21" color monitor. The instructor in the classroom has intercom to the instrument operators to make it somewhat an interactive system which could be very useful for teaching small classes.

The EROS Data Center has numerous 3/4" video cassette programs available which they will duplicate for anyone sending a blank video cassette. Purdue uses videotapes in their continuing education programs.

Computer Assisted Instruction (CAI)

Advantages

In contrast to humans, the computer never gets tired, distracted, angry, sarcastic, impatient or forgetful, unless a human builds these qualities into it. The computer can accommodate many students at once, making the student feel like he has someone's personal attention. The computer can service many students many miles away through the use of terminals and connect lines. The computer can relieve an instructor of many tasks and can perform certain functions with less error and more speed than a human instructor.

Limitations

Computers are very expensive and the cost per student credit hour is still as high as any traditionally taught course. Initial programming for a course is very demanding and usually takes more time than any other course preparation. The computer, like many other devices, can be relied on too heavily. Oettinger (ref. 36) has an extensive list of criticisms of the computer, too extensive to enumerate here.

Uses

As far as is known computers are not used in the instructional technology sense in remote sensing education. Of course computers are used extensively in remote sensing education because of the nature of the discipline which requires the manipulation of large amounts of data. Since computers are a normal part of many programs in remote sensing, it would not be a difficult transition to make instructors and students aware of and use the instructional technology uses of the computer.

Programmed Instruction

Programmed instruction includes materials and in some cases a teaching machine which presents the program. The machine simply gives the student access to the material and controls the advancement of the material based on the student's response. This type of instruction is usually related to CAI.

Advantages

The student can move at his own pace and knows his progress at all times. The programmed material is usually designed to follow a logical sequence and therefore the student does also. Programmed material uses a variety of media which can be more stimulating for the student.

Limitations

Programmed instruction is not easily adapted to learning which requires feeling or emotions, although this may not be a concern for most sciences. Some programs can be rather dull, especially for the brighter students. Programmed materials can be expensive and very time consuming to prepare.

Uses

Programmed materials are plentiful in the field of education in general, but are lacking in the remote sensing field. There are only a few generally available to the profession--those which can be purchased

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at Purdue and the Technology Applications Center. There are locally produced programs like Paine's and Ulliman's, and possibly more, but these may not be suitable for direct use. A set developed by Ulliman was sold to the University of Washington and another loaned to North Idaho College, but it was recommended they not be used directly in their courses; rather, they could best serve the purpose by being guides for the development of local material suited to the instructor and the course.

FOOD-FOR-THOUGHT

Based on the background gained in writing this paper and the status of multimedia in remote sensing, I would like to provide some food for thought to get us thinking about multimedia needs and means of obtaining those needs before the week is out.

1. There are apparently significant advantages of using instructional technology in remote sensing. In fact we already use much of the hardware and software normally associated with instructional technology and yet there is a lack of the pedagogical aspects of instructional technology used in remote sensing. Therefore, there seems to be a great potential for increasing the use of instructional technology in our field.

2. Most uses of instructional technology are by individual instructors who have the incentive to find funding and develop the programs. There is no organized effort to determine the present status and needs of remote sensing educators and assist them in finding funding or audio-visual material, or developing necessary programs.

The one group which might logically do this, the Committee on Education and Interpretive Skills of the American Society of Photogrammetry (ASP), is not equipped with either manpower or funding to accomplish such a task. The three subcommittees of the group, Textbooks, Instructional Materials, and Educational Programs, have just gotten off the ground in the last few years and have had some notable accomplishments in the form of surveys and published articles, a number of which are in the March 1977 issue of Photogrammetric Engineering and Remote Sensing.

The Instructional Materials subcommittee recently surveyed the need for and possible methods for exchanging slides among interested members. They found little agreement on either: (a) how a slide exchange program might be conducted or, (b) what types of materials would be appropriate. Slide exchange programs do not seem to be a solution.

3. The National Aeronautics and Space Administration (NASA) or the EROS Data Center (EDC) either directly or through some other facility, e.g. the Technology Applications Center, could provide assistance in this area in possibly a number of ways such as:

a. Direct financial assistance.

b. Materials, facilities, manpower assistance.

c. Development of fairly standardized hardware or software to be made available at a nominal fee.

d. Initial development assistance with publishers and other producers of educational material to develop programs and materials to be made available at a reasonable cost. Educational technology may be one area in remote sensing that meets the maturity test for private enterprise to pursue (ref. 37).

e. Production and annotation of broadly applicable materials which are most appropriate to that agency. For example, NASA develops slide tape programs of the LANDSAT and U-2 programs and makes these available to educators at a minimum over-cost fee.

4. Many more books on remote sensing are becoming available. We might encourage the authors, through an established group like that mentioned above, to also develop workbooks, programmed instruction, 35mm slides, overhead transparencies, slide/tape programs or other audiovisual material. This could be done through monetary or other assistance.

5. Once instructional technology needs are defined, then problem-solving, instructional technology techniques need to be correlated with the needs and communicated to instructors. At the same time, instructors should be encouraged to examine their present teaching methods and consider other, possibly more efficient ways of teaching and helping students to learn. This could be done by the ASP Committee on Education and Interpretive Skills if it is given sufficient support. One of the goals of this committee now is to encourage and assist in the development of teaching instruments and devices (ref. 38). With the necessary assistance they could develop high quality instructional material and demonstrate it at conventions like the American Society of Photogrammetry's annual convention. The committee might also consider conducting a shortcourse to assist instructors in identifying and using the appropriate instructional technology.

6. Miller (ref. 28) noted that no computer had been specifically designed for educational needs, except possibly the ILLIAC computer

because of its pattern recognition capabilities. Access to the ILLIAC or ARPANET would be advantageous for teaching remote sensing at educational institutions although most could not afford to pay for the complete line charges and computer time. Some consideration should be given to assistance in this area.

7. Very few of us can take the time or effort to become an expert in instructional technology or even in a major aspect of it, such as programmed instruction. That is why there are people at most colleges and universities who may go by the title "instructional technologist" to assist instructors in developing appropriate instructional programs for their courses. I recommend we contact these specialists to learn what we can do to become better teachers.

There are many other possibilities which we may develop during this conference. This is a beginning and I am hopeful that something very useful will evolve.

> The world stands out on either side
>   no wider than the heart is wide;
> Above the earth is stretched the sky,
>   no higher than the soul is high.

Edna St. Vincent Millay ("Renascence 1917")

Table 1. Comparative Instructional Costs Per Student Hour of Credit for 50 Students and 150 Credit Hours (from Brooks and Leth, ref. 14).

Model	Cost ($)	Cost($)/Student Credit Hour
Traditional		
Professor (6 hr load)	5580	37.20
Assoc. Prof. (6 hr load)	4490	29.90
Ass't. Prof. (6 hr. load)	3590	23.80
Teaching Assistant (6 hr load)	1700	11.33
Nontraditional		
CMI or CAI	3000 (computer 1700 (TA)	31.33
Mass lecture and TA	600 (Ass't. Prof.) 1700 (TA)	15.33
Self-Instruction and TA	Students buy modules 1133 (2/3 TA)	7.55

APPENDIX A

Specified goals for different media techniques.

Media Technique	Goal
Books	Knowledge, critical thinking
Lecture	Knowledge, inspiration, identification with scholar, critical thinking
Discussion	Critical thinking, relate knowlege to attitude change
Guest lectures	Added interest and information
Films	Material more concrete, facilitates learning, involves motion, interest
Television	Interest, motion, visual details
Slides	Materials greatly enlarged, interest
Bulletin boards, displays	Provide opportunity for learning at students pace, concrete examples
Recordings	Auditory experience
Field Trips	First hand experience, first hand knowledge, interest
Laboratory	First hand experience, scientific method
Study guide, workbooks	Aid organization and learning of materials, promote application of knowledge
Periodicals	Bridge gap between classroom and other experiences
Teaching machines	Learning knowledge and skills, particularly those requiring repetitive and immediate feedback

APPENDIX B

A LIST OF MEDIA – MATERIALS AND EQUIPMENT

Real Materials and People	*Projected*	*Audio*	*Printed*	*Display*	*Multi-Media*	*Programmed Instruction*
People	Opaque projection	Lecture	Flash card	Bulletin board	Teaching machine	Book format
Events	Overhead transparency	Record	Textbook	Enlarged hinged visuals	Multi-media kits	Teaching machine format
Objects	Filmstrip	Cassette tape	Workbook	Blackboard	Slide, tape programs	Computer assisted instruction
Demonstrations	Slides	Reel-to-reel	Study guides	Flannel board	Motion pictures	
Simulations	8 & 16 mm film		Periodicals	Photo print	CCTV	
Models	Microfilm		Computer printer	Charts		
Field trip	Computer CRT			Graphs		
Specimens				Globes		
Laboratory				Maps		

APPENDIX C

SOURCES FOR EQUIPMENT AND MATERIALS

For most hardware, see the Audio-Visual Equipment Directory.

1. OVERHEAD PROJECTOR AND TRANSPARENCIES

There are many source guides for overhead projectors; one of the best is the latest Audio-Visual Equipment Directory. Transparencies for the overhead are plentiful at the elementary and secondary school level, and in some subjects at the university level. R. R. Bowker Co., 1180 Avenue of the Americas, New York, N.Y. 10036, publishes an "Index to Overhead Transparencies" which lists 18,000 transparencies. As far as is known there are no generally available commercial transparencies covering the field of remote sensing.

2. 35MM AND LANTERN PROJECTORS AND SLIDES

*Canon U.S.A., Inc., 64-10 Queens Boulevard, Woodside, NY 11377
*Motiva, Ltd., 155 East 55th Street, New York, NY 10022
*Realist, Inc., Megal Drive, Menomonee Falls, WI 53051
*Spindler and Sauppe, Inc., 1329 Grand Central Avenue, Glendale, CA 91201

3-D Projectors

*DeHavilland Aircraft Co., Toronto, Ontario, Canada (for Jackson's device)

*Albion Instrument Co., 2 Albion Road, Folkestone, Kent, England (for the Hawk MK VI stereoprojector, $800; individual slides are not adjustable)

*Buhl has developed a side by side dissolve base system which might be applicable for 3-D projection, except for the set, short focal length lenses. Buhl Projector Company, 60 Spruce Street, Paterson, N.J. 07501

Slides, Slidesets or Slide/Cassette Programs Specific to Remote Sensing

*EROS Data Center, USGS, Sioux Falls, SD 57198 (slide-cassette programs)

*Continuing Education Administration, 116 Stewart Center, Purdue University, West Lafayette, IN 47907 (minicourse series, slide/cassette programs materials)

*Technology Applications Center, The University of New Mexico, Albuquerque, NM 87131 (slide programs and annotated educational slide sets)

*Pilot Rock, Inc., Box ZZ, Arcata, CA 95521

*Harper and Row Publishers, Inc., 10 E. 53rd Street, New York, N.Y. 10022 (annotated slides with booklet on satellite views of vegetation and land forms)

*John Wiley & Sons, Inc., 605 3rd Street, New York, N.Y. 10016

*McGraw-Hill Book Company, 330 West 42nd Street, NY 10036

*Audio-Visual Instruments, 6839 Quadapule Trail NW, Albuquerque, NM 87107

May be appropriate to remote sensing

*GEO-PUB Media, Tualatin, OR 97062

*Eastman Kodak Co., Motion Picture and Education Markets Division, 343 State Street, Rochester, NY 14650

*Wards Natural Science Establishment, Inc., 3000 East Ridge Road, Rochester, NY 14605

*Hubbard, 2855 Shermer Road, Northbrook, IL 60062

3. TAPE RECORDERS AND RECORDINGS

The source of tapes for the EDC, Purdue and the Technology Applications Center are given under slide sources. For tapes in general, the best reference is the National Audio Tape Catalog, Department of Audiovisual Instruction, National Education Association, 1201 16th Street, NW, Washington, D.C. 20036.

4. MOTION PICTURE FILM PROJECTORS AND FILMS

*EROS Data Center, USGS, Sioux Falls, SD 57198 (Films: numerous)

*Program Development Manager (Edward Zaitzeff) Earth Resources, Bendix Aerospace Systems Division, Ann Arbor, MI 48107 (Films: "You and M-DAS" and "The World of Invisible Color")

*Pacific Southwest Forest and Range Experiment Station, 1960 Addison Street, Berkeley, CA 94701 (Film: "A Certain Distance")

*National Film Board of Canada (Film: "The Forest Watchers")

*U.S. Agency for International Development, Department of State (Film: "Images of Life"--a film explaining the benefits and significance of LANDSAT to the layman)

*The Information Office, U.S. Geological Survey, Washington, D.C. 20242 (Films: Five films on Aerial Photo Interpretation)

5. EDUCATIONAL AND INSTRUCTIONAL TELEVISION

*EROS Data Center, USGS, Sioux Falls, SD 57198 (numerous 3/4" tapes)

*Continuing Education Administration, 110 Stewart Center, Purdue University, West Lafayette, IN 47907

6. COMPUTER ASSISTED INSTRUCTION

Most people are aware of the sources for the computers (hardware) and they are listed in numerous sources including Gerlach and Ely (ref. 12). Those same manufacturers are a point of contact for software also. Other contact organizations are:

*Computer and Information Science Research Center, Ohio State University, Columbus, Ohio 43210

*Computerized Courseware Clearinghouse, University of Wisconsin, Green Bay, WI 54302.

7. PROGRAMMED INSTRUCTION

Teaching Machines

The Audio Visual Equipment Directory

Programmed Materials

Many publishers as listed in Gerlach and Ely (ref. 12)

*Carl H. Hendershot's Programmed Learning. A Bibliography of Programs and Presentation Devices, Carl H. Hendershot, Bay City, MI

*Continuing Education Administration, 116 Stewart Center Purdue University, West Lafayette, IN 47907

*Technology Applications Center, The University of New Mexico, Albuquerque, NM 87131

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COMPUTER APPLICATIONS IN REMOTE SENSING EDUCATION

Ronald L. Danielson

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Computer applications to instruction in any field may be divided into two broad generic classes: computer-managed instruction (CMI) and computer-assisted instruction (CAI). The division is based on how frequently the computer affects the instructional process and how active a role the computer takes in actually providing instruction. Both classes have been used in many different subject areas and many different age groups, from elementary school reading to graduate-level science and engineering courses. References 1 and 2 discuss various aspects of computer uses in education in much more detail.

Although the author is not aware of any applications of either CMI or CAI to remote sensing education, there are no inherent characteristics of the subject which preclude use of one or both techniques, depending on the computer facilities available to the instructor. This paper will first summarize the characteristics of the two classes, then briefly discuss potential applications to remote sensing education, and advantages and disadvantages of computer applications to the instructional process.

1. Computer-Managed Instruction

In CMI, the computer is not used to directly instruct the student; rather, the computer assumes the role of advisor (or overseer, depending on the amount of coercion the system may employ). Based on the individual student's performance statistics (topics covered, exam and quiz scores, etc.) and the course performance objectives established by the instructor, the computer determines the need for remedial work, the possibility of skipping detailed coverage of upcoming topics, and subjects to be covered before the next exam (reference 3). This determination is presented to the student as a series of topics to be studied in a given time period, say the next week. Periodically (again say, weekly), the computer outputs a summary of each student's progress to the instructor, allowing him to pinpoint students in serious trouble and provide counseling, or to identify students making rapid progress, who are perhaps candidates for advanced or additional topics.

CMI may be implemented on a batch or interactive computer system of virtually any size (microprocessor to mainframe), although an interactive system allows both participants in the advising to ask for clarification, as needed. The advantages of CMI include a more-or-less individualized curriculum for each student, as well as the detailed knowledge the instructor gains on the status of each student. The primary disadvantage is that the instructor must break each course into a fairly large number of very well-defined instructional units, establish a prerequisite-sequel relationship among the units, and define criteria by which a student's progress may be measured. In addition, the instructor must program (or design and have programmed) the advising routine, unless some general-purpose CMI program exists on a computer to which he has access.

CMI may be used alone, but it is frequently used in conjunction with the other generic class, computer-assisted instruction.

2. Computer-Assisted Instruction

In CAI, the computer takes an active role in educating the student. The system presents information, asks questions, judges student answers, and corrects wrong answers. CAI systems are all interactive systems, in which the student sits at a terminal and engages in a dialog with the computer system. There are three dimensions along which CAI systems may be further subclassified: (1) type of computer on which the system runs, (2) type of terminal and input/output (I/O) devices used by the system, and (3) type of dialog between system and student. Let's consider each dimension in turn.

2.1 *Type of computer*– There are three categories of computer used in CAI systems: large mainframe systems capable of supporting 100 to 500 or more simultaneous users, minicomputer-based systems capable of supporting two to 100 simultaneous users, and self-contained single-user systems based on a microcomputer.

Mainframe systems have the advantage of large amounts of storage and processing power available, and the disadvantages of high cost, and the fact that if the computer goes down, all users are inconvenienced. Microprocessor-based systems are low in cost, which means that several can be purchased, allowing continued instruction for some students should one system fail. On the other hand, microcomputer-based systems are very limited in terms of processing power, memory capacity, and long-term storage availability. Minicomputer systems are significantly cheaper than mainframes and can offer nearly as much memory and long-term storage capacity. They offer considerably more processing power than the microcomputer-based systems. Unfortunately, they share with mainframe systems an inability to gracefully degrade services in case of failure.

2.2 *Type of I/O devices*– The primary I/O device in any CAI system is the terminal through which the student and the system communicate. Again, there are three categories of terminal suited to CAI in remote sensing: (1) hardcopy output with keyboard input (e.g., teletype), (2) line-oriented CRT display with keyboard input, and (3) raster scan graphic display (either black and white or color) with keyboard input. In addition, there are a number of special I/O devices which may supplement the basic terminal. Special input devices include those used to position a cursor or select from a "menu" of actions on a CRT display (light pen, touch panel, joystick). Special output devices include computer-controlled slide projectors and various voice output devices.

Hardcopy terminals are slow and relatively noisy compared to CRT displays. Since the price of graphics displays (particularly black and white displays) is now much closer to that of line-oriented displays, and the graphics capability greatly enriches the dialog between student and system, new CAI systems which are being purchsaed or developed should specify graphic CRT displays as the principal terminal output device. Of course, color CRT displays are ideally suited for use with multispectral image data. Either type of graphic display should have a minimum resolution of 256 × 256 points, and preferably 512 × 512 or 1024 × 1024 points.

With regard to special I/O devices, a joystick or trackball is very useful for cursor positioning for some remote sensing tasks (e.g., reference point selection) and would be equally suited for computer-assisted instruction in those tasks. A computer controlled slide or microfiche projector would have utility in instruction in activities such as photo interpretation. In addition, any other peripheral input or output device used in remote sensing applications, such as a digitizer, may be used as an I/O device for CAI.

2.3 *Type of dialog*– The simplest dialog between student and system is drill and practice, in which the computer asks the student a number of short-answer questions, judges and criticizes the answers, and determines the difficulty and subject of future questions based on the student's past performance. Such a dialog makes minimal use of the computer's capabilities, but is suited for use with the statistical and mathematical skills important in remote sensing. In fact, CAI systems based on such simple dialogs have had great success when employed as remedial devices to improve mathematical skills (reference 4).

A second type of dialog is an inquiry dialog, in which the student asks questions of the system in some query language, the system calculates (or searches a data base for) the answer, and responds. There is a tradeoff between ease of use by the student and complexity of the CAI system, determined by such factors as the query language (e.g., predicate calculus vs natural language) and size of the data base. Such dialogs, using simple natural language input, have been employed in teaching subjects such as geography (reference 5) or electronic troubleshooting (reference 6), as well as in computer-managed instruction (reference 7). An inquiry dialog might have utility for allowing a new student in remote sensing (say, an expert in urban planning just beginning to use remote sensing techniques) to read a fairly technical overview of the subject and have new terms and concepts explained in whatever detail he wishes.

As opposed to the student control evident in an inquiry dialog, a Socratic dialog vests control of the dialog in the computer. The system asks the student a series of carefully planned questions, each dependent on the student's previous answers, in order to lead the student to discover "by himself" the desired concepts and conclusions. While such a dialog may seem an ideal vehicle for teaching, an implementation in a CAI system requires solving a number of complex problems, such as computer understanding of virtually unrestricted natural language input. Consequently, an unrestricted Socratic dialog is not currently a viable CAI technique, although such dialogs have been implemented in well-defined problem domains (reference 8) and research is continuing in this area.

A type of dialog which is eminently suited to use in remote sensing education is a simulation dialog, in which the system simulates the effects of the student's choice of parameters on the final outcome of a process. For example, a CAI lesson on classification of LANDSAT images might provide the student with several possible choices of parameters at different points in the process, and then display the results in a classification using those parameters. There is seldom enough computer power available to allow such classification to take place in real time, but by prestoring the results of those classifications, a CAI system can simulate allowing the student to experiment with different parameter choices. Such simulation dialogues are frequently coupled with inquiry or restricted Socratic dialogs to greatly enrich the educational process (reference 5).

CAI can also be used as an on-line training aid. The student begins a remote sensing process interactively on a computer, and when he reaches a point of uncertainty, typing HELP on the terminal enters him into an inquiry dialog explaining the pertinent points, and perhaps even guiding him through the next few steps. At any point, he may return to the process and continue unaided.

A final type of CAI dialog is one between the system and instructor, rather than the system and student. The purpose is to help an instructor prepare exams, either for administration on-line, as part of other CAI activity, or off-line, in a traditional classroom situation. Such automated test construction dialogs employ large pools of short-answer or multiple choice questions, as well as problem generators of varying complexity.

3. Remote Sensing Activities Suited to Machine-Aided Instruction

While virtually all remote sensing activities may be taught using some form of machine-aided instruction, some tasks seem more naturally suited for certain dialog styles than others. As already mentioned, the mathematical aspects of remote sensing and statistics are well suited to drill and practice, and tasks such as clustering and classification of images may be treated via simulation to provide the student experience he might otherwise not obtain.

With the addition of extra I/O devices, activities such as photo interpretation or digitizing may be taught via CAI. Selection of ground truth areas or reference points for geometric registration may be done if the display is equipped with a light pen or trackball. For some of these tasks, of course, it may be necessary to provide additional printed material which the student will use during his terminal session.

4. Advantages and Disadvantages

As with the use of any technology, there are advantages and disadvantages to use of machine-aided instruction. Not the least of the disadvantages is that a certain small percentage of all students have extreme difficulty becoming accustomed to the machine, and never receive an acceptably high level of instruction (reference 9). On the other hand, in a field such as remote sensing, where computers have a large impact on the actions a student will take in performing many tasks, it is important that students develop an early familiarity with computers. Using computers in the instructional process itself is a very effective way of fostering that familiarity.

Other disadvantages of machine-aided instruction are that it is time-consuming to implement CAI material (as much as 50-100 hours of preparation for each hour of student contact, depending on lesson-development aids available) and that there must be easy, frequent and inexpensive access to a computer system.

The advantages of machine-aided instruction are that the material developed may be used by many students (serially or simultaneously), that the pace of instruction and topics taught can be individualized to a large degree, and that certain CAI techniques (e.g., simulation) allow a student to perform experiments or activities which he would not be able to otherwise.

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TEXTBOOKS AND TECHNICAL REFERENCES FOR REMOTE SENSING

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A few years ago, a paper on this topic would have had an extremely abbreviated section on textbooks. There still is considerable imbalance, especially since technical references constitute a broader category which includes government and industry manuals; but the number of textbooks on remote sensing and photointerpretation has increased substantially in recent years. Indeed, there are now enough books in print that to attempt to comment on all of them as well as technical references would make this an extremely long article. Hence each author comments on a few selected works in his category, the selection being based on personal experience and choice. Introductory texts on remote sensing are discussed by Rudd, advanced remote sensing texts by Bowden, photointerpretation books by Colwell, and remote sensing technical references by Estes.

The bibliography is a selected one also. Although it goes substantially beyond those commented upon herein, there are many useful works which were not included for reasons such as the proportion of the work devoted to remote sensing. No attempt at all is made here to survey individual articles in the periodical literature; their numbers are legion.

Introductory Remote Sensing Textbooks. During the early 1970s as courses on or including remote sensing began appearing in some numbers, books on the subject were very few in number. Instructors were relying on articles in journals, government publications, industrial advertising material, research grant reports, etc. Almost as soon as it appeared, The Surveillant Science (ref. A-8) quickly became the commonly used text for courses being offered at a variety of levels. It affords breadth of subject matter as well as variation in technical difficulty, being comprised of many articles, the majority of which previously had appeared in diverse publications. Holz provided an organized approach, a grouping of articles on related subjects, and introductory sections to tie the several units together. It is questionably a beginner's book, although the publication dates of the articles do reflect a time when less reader background was presumed, a useful feature.

Two more books which have enjoyed wide use in introductory courses appeared a year later, Rudd (ref. A-27) and Estes and Senger (ref. A-6). Estes and Senger also is a book with multiple authors; however, each of the chapters was written specifically for this book. Moreover, the original purpose of the writing was for use in an IGU workshop to introduce remote sensing to meeting attendees, so it was intended to be an introductory level book. It continues to enjoy substantial use although variations in style and technical level of the chapters are found objectionable by some. Rudd has the least depth of any of these books but perhaps the most breadth, extending beyond application to a philosophical consideration of implications. Although it does include a chapter on principles, it was intended to provide a total overview of and to interest the reader in remote sensing. It has been used most successfully as an introduction to the technique.

Everyone's Space Handbook (ref. A-11) is primarily a photo imagery source manual, although the first half of this paperback provides an introduction to image characteristics, sensors, sensor platforms, and imagery types. For the person needing specifics regarding what kinds of imagery are available and where to obtain them, this is one of the more concise references routinely available.

An introduction to remote sensing which focuses on technique principles to the exclusion of application is available in Fundamentals of Electromagnetic Remote Sensing (ref. A-14). The physical and mathematical principles which provide the foundation for remote sensing are given rather more prominence in this treatment than in many other introductory books. At present available only as a paperback, an expanded version of this book with a co-author is to become available in the near future.

Back when only the first few books on remote sensing were available, many questioned whether any of them was actually a textbook. One effort which resulted from this dissatisfaction was the collaboration of over 20 authors on a book sponsored by the National Council for Geographic Education (ref. A-26). The book is intended as a text rather than a reference, and it is aimed at the introductory level. A lab manual which utilizes illustrations in the text also is available although the textbook is self-contained. Remote sensing lab exercises and/or lab materials commonly pose a problem for people setting up a new course. The January 1977 issue of the Association of American Geographers' Remote Sensing Committee (ref. C-17) publication, RSEMS, is devoted to lab exercise ideas appropriate to introductory courses; a few lab manuals such as Lee (ref. A-13) and one from Pilot Rock, Inc., are obtainable.

There are several other books including some recent ones which could be classed as introductory, depending upon the nature of the course in question. Those discussed above, however, include the books which have been most used in the past five years in introductory remote sensing courses in the United States.

Advanced Remote Sensing Textbooks. The American Society of Photogrammetry (ASP) has produced a series of advanced manuals that are somewhere between textbooks and reference manuals. The first was the Manual of Photogrammetry (ref. B-22) followed by the Manual of Photographic Interpretation (ref. B-4). The Manual of Color Aerial Photography (ref. B-20) was the third of the series and was followed by the two-volume Manual of Remote Sensing (ref. A-23). The Manual of Remote Sensing is being revised to be published as a second edition in 1981.

The ASP manuals were never intended as textbooks but were sometimes used as such because of the lack of comprehensive texts. Often instructors choose something like Interpretation of Aerial Photographs (ref. B-2) as a basic text with supplemental assignments in the above manuals.

In the late 1960s and early 1970s, several specialized books appeared such as *Remote Sensing: With Special Reference to Agriculture and Forestry* (ref. A-25); *Remote Sensing in Ecology* (ref. A-10); *Aerial Photo-Ecology* (ref. B-10); and *City Planning and Aerial Information* (ref. B-3), to name a few. Except in very specialized courses, the above books were usually treated as the manuals were--as supplemental reading.

During the last half of the 1970s, several new books were published which are specifically aimed at advanced classes. *Remote Sensing for Environmental Sciences* (ref. A-29); *Remote Sensing, Principles and Interpretation* (ref. A-28); and *Remote Sensing of Environment* (ref. A-15) are three examples. A few specialized books such as *Remote Sensing in Geomorphology* (ref. A-36) and the more quantitative approach found in *Remote Sensing, the Quantitative Approach* (ref. A-34) also became available.

Most advanced texts and reference books are multi-authored. Lintz and Simonett, Swain and Davis, and all of the ASP manuals have numerous authors. In contrast, Avery, Sabins, Howard, and Branch are examples of single-authored books. Both approaches have advantages and disadvantages. The multi-authored books bring a wider range of knowledge, experience, and information but are often clipped, distractive, and troublesome for the student due to changes in writing style and flow of communication. Single-authored books tend to be better organized, consistent in style, but may be shallow or lacking in specialties other than the author's. While there is probably no solution to some of the above problems, we have yet to try the two- or three-author comprehensive text that may fill the gap.

Photo Interpretation Books. Photo interpretation is dealt with to a significant extent in virtually all introductory and advanced remote sensing textbooks, including those reviewed in the previous two sections. This is explained by the fact that man's use of the term "remote sensing" has been broadened in recent years to include not only the acquisition but also the analysis of remote sensing data, including photographs.

The Manual of Photographic Interpretation (ref. B-4) is the only comprehensive book on photo interpretation per se that ever was written. Despite its 1,000-page size, it has been used very successfully in past years as the textbook for courses in photo interpretation. Despite the fact that it was written nearly two decades ago, it still is current in nearly every aspect of photo interpretation except that dealing with the optical and electronic enhancement of aerial and space photographs as an aid to their interpretation.

The decision to prepare this "first comprehensive treatment of the subject of photo interpretation" was arrived at by the American Society of Photogrammetry shortly after that society took the lead in establishing the Commission on Photo Interpretation (Commission VII) within the International Society of Photogrammetry in 1952. It was agreed that this was to be a truly international textbook or manual in terms of the contributions contained in it. In the year of its publication, The Manual of Photographic Interpretation received a prize from the American

Library Association for being one of the "best technical books of the year."

Work on the Manual began in 1955 and was culminated with publication in 1960. More than 100 distinguished authors contributed to the book, all of them without remuneration. To the contrary, many of them abandoned their plans to publish a book in their own right, complete with the royalties that would be realized by their so doing, in order to contribute to the Manual of Photographic Interpretation.

The first three chapters of the Manual are introductory in nature and deal with the following topics, respectively: I. The Development of Photo Interpretation; II. Procurement of Aerial Photography; and III. Fundamentals of Photo Interpretation.

The next 12 chapters deal with applications of photo interpretation in the following respective disciplines: Geology, Soils, Engineering, Forestry, Wildlife Management, Range Management, Hydrology and Watershed Management, Agriculture, Urban Area Analysis, Archaeology, Geography, Special Forms of Photo Interpretation. (Note the tendency to begin with the barren landscape by having the geology chapter first in this series, then the vegetated landscape, and finally the cultural landscape.)

The concluding chapter of the Manual deals with Education and Training in Photo Interpretation and, as such, contains much material which still is of sufficient validity to merit its being brought to the attention of the CORSE-78 attendees.

An initial printing of 10,000 copies of this Manual was made; that supply was almost completely exhausted within six months, with the result that an additional printing of 5,000 copies was made, after which the type was broken down at the request of the publisher. While this book is currently out of print, college and university libraries commonly have sufficient copies of it on the reserve bookshelf to permit its use as a supplemental reference for basic courses and also as the primary textbook for smaller, more advanced courses in photo interpretation.

One of the most commonly used textbooks dealing primarily with photo interpretation is Avery's Interpretation of Aerial Photographs (ref. B-2). Although it is by no means as comprehensive as The Manual of Photographic Interpretation, it is of appropriate size and content for use as the textbook for almost any basic course in photo interpretation. In terms of subject matter and organization, its contents are similar to those of The Manual of Photographic Interpretation. Specifically, while it contains, quite appropriately, a certain amount of introductory material dealing with historical aspects, means for procuring photography, and the basic principles of photo geometry, stereoscopy, and photo interpretation techniques, the remainder of the book is discipline oriented. As a result, the reader can become familiar with photo interpretation in such disciplines, chapter by chapter, as forestry, range management, agriculture, urban area analysis, and land use planning. Representative problems at the end of each chapter add to the book's usefulness.

The National Aeronautics and Space Administration, in connection with its Earth Resources Survey Program, has published several books that satisfy the need felt by most photo interpretation teachers for numerous photographic illustrations of high quality, and especially in full color. In most instances the photographs appearing in these NASA books are fortified with annotations and captions, prepared and field-checked by highly competent photo interpreters, thereby making the books largely self-sufficient for teaching certain important aspects of photo interpretation. Since these books have been published in large quantities by the Government Printing Office, they are both readily and economically available. The specific types of photography that are primarily dealt with in these books are indicated by their titles. Included among them are the following: "Earth Photographs from Gemini 3, 4, and 5" (ref. B-8); "Monitoring Earth Resources from Aircraft and Spacecraft--the Apollo 9 Multiband Photographic Experiment" (ref. B-16); "Mission to Earth: Landsat Views the World" (ref. A-17); and "Skylab Explores the Earth" (ref. A-33).

Remote Sensing Technical References. As stated above, this is an extremely broad area, and any attempt to encompass it totally is doomed to failure. It is an area of remote sensing literature which is important, however. Indeed, owing to the nature of the development of the field, technical references have played a key role in the dissemination of knowledge concerning advances in basic and applied research techniques, methodologies, and instrumentation.

In the early 1960s, as the field began to evolve from photo interpretation, there were few professional publications which would accept articles on the subject aside from Photogrammetric

Engineering (ref. C-8), the house organ of the American Society of Photogrammetry. Many other scholarly journals would not accept articles in the field, considering their contents too "technique-oriented." Happily, in many disciplines this state of affairs has begun to change as the caliber of research matures and the degree of interest in the area increases. Nevertheless, some vestiges of this type of thinking may still be found in the editorial policies of a number of professional journals.

Owing to this lack of outlets for publication of research results, technical reports and symposia began to play an important role in the dissemination of information concerning progress in the field; this role has carried forward into the present time. Researchers learned to "get on the lists," that is, to write to request that their names be added to the mailing lists of universities or government agencies conducting research of interest to them. Institutions such as the Forestry Remote Sensing Laboratory, University of California, Berkeley; The Center for Research in Engineering Science (later Center for Research, Incorporated), University of Kansas; Laboratory for Applications of Remote Sensing at Purdue; and the Willow Run Laboratories (now Environmental Research Institute of Michigan) and the University of Michigan, to name some of the leaders, were bombarded by requests from researchers.

Today this is still an excellent way to keep up with the field. Because the lag time for publication in refereed journals is typically six months to two years, in some cases it pays the serious researcher to write for the technical reports from individuals conducting research of particular interest to him. Typically these individuals are more than willing to send copies of their latest works, if available. The only drawback to this procedure is that responses to such requests, understandably, often are in Xerox form without original illustrations.

As remote sensing began to grow and outlets for publications were sought, symposia played an important role in getting the word out. The Proceedings of the Symposia on Remote Sensing of Environment, now the International Symposium on Remote Sensing of Environment (ref. C-11), held at the University of Michigan (most recently held in Manila in the Philippines) played an early key role in bringing individuals in the field together to discuss the results of their research. As the field has grown, so has the number of symposia sponsored both by private institutions and governmental agencies. The University of Tennessee's symposia on Remote Sensing of Earth Resources (ref. C-15), the National Aeronautics and Space Administration's (NASA) Significant Results Symposia (variously titled, but most recently NASA Earth Resource Survey Symposia [ref. C-6]), NASA's Active Microwave Workshop Proceedings (ref. A-16), and the United States Geological Survey's and National Aeronautics Space Administration's Pecora Symposia (ref. C-12) are but a few of the increasing number of meetings which produce proceedings, not to mention those held by societies which have remote sensing emphasis on sections such as: the Proceedings of the Annual Meetings of the American Society of Photogrammetry and Remote Sensing (ref. C-10).

As the field has grown, so too has the number of books which may be considered technical references. Works such as Wolfe's Handbook of Military Infrared Technology (soon to be updated and retitled Handbook of Infrared Technology) (ref. A-41), Skolnik's edited work Radar Handbook (ref. A-32), Jensen's Optical and Photographic Reconnaissance Systems (ref. B-11), and Pratt's work on Digital Image Processing (ref. A-21) are but a few of the burgeoning lists of publications in this growing area.

It should be stressed in conclusion that this discussion of technical references is by no means complete. In addition to reports developed in NASA; the Department of Interior and its EROS program; the Geography Program of the Geological Survey; private industries such as General Electric Space Division, Earth Satellite Corporation, Goodyear, Lockheed, Westinghouse, Texas Instruments, and Motorola also produce technical works detailing the results of their research in remote sensing. The best advice to the reader on which to end this section is: keep your eyes and ears open and your pencils, pens, or dictaphones ready. When you hear of a report by an agency which is pursuing research in your area of interest, write for it or ask to be put on their publication mailing list.

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29. Wenderoth, S., Yost, E., et al., Multispectral Photography for Earth Resources, West Hills Printing Co., 1972.

C. Periodicals, Etc.

1. CCRS Current Publications, Canada Centre for Remote Sensing, Ottawa.

2. Geo Abstracts. Remote Sensing and Cartography, Section G, Norwich, England.

3. The I.T.C. Journal, International Institute for Aerial Survey and Earth Sciences, Enschede, The Netherlands.

4. Landsat Data Users Notes, EROS Data Center, Sioux Falls.

5. Landsat Newsletter, NASA, GSFC, Greenbelt.

6. NASA Earth Resources Survey Symposium--Proceedings, JSC, Houston.

7. Photogrammetria, The International Society for Photogrammetry, Amsterdam.

8. *Photogrammetric Engineering and Remote Sensing*, Amer. Soc. of Photogrammetry.

9. *Proceedings for the Annual Purdue Symposium on Machine Processing of Remotely Sensed Data*, The Institute of Electrical and Electronics Engineers, Piscataway, N. J.

10. *Proceedings of the Annual Meeting*, Amer. Soc. of Photogrammetry.

11. *Proceedings of the International Symposia on Remote Sensing of Environment*, Willow Run Laboratories, Univ. of Michigan, 1962-1977.

12. *Proceedings of the William T. Pecora Memorial Symposia*, U.S.G.S., EROS Data Center.

13. *Quarterly Literature Review of the Remote Sensing of Natural Resources*, T.A.C., Univ. of New Mexico.

14. *Remote Sensing for the Inventory and Management of Natural Resources*, Procedural Manuals Series, Remote Sensing Program, Space Sciences Laboratory, Univ. of California.

15. *Remote Sensing of Earth Resources*, Univ. of Tennessee Space Institute.

16. *Remote Sensing of Environment*, Elsevier North-Holland, Inc., New York.

17. *RSEMS*, Remote Sensing Committee of the Association of American Geographers.

18. Technical Reports, Remote Sensing Laboratory, CRES, Univ. of Kansas.

19. Technical Reports and Memoranda, Jet Propulsion Laboratory, California Institute of Technology.

WORKSHOP SUMMARY PAPERS

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Southern California - Arizona

Regional Academic Workshop

June 28, 1978

Workshop Chairman: Dr. Leonard W. Bowden, University of California, Riverside

Workshop Panel Members:

Dr. John E. Estes, University of California, Santa Barbara
Dr. William A. Finch Jr., San Diego State University
Dr. Phil N. Slater, University of Arizona

The workshop convened at 8:40 a.m. with nine attendees and four panel members. During the approximate two hours of discussion, more people kept arriving until a total of twenty three people attended and participated in the session. This paper is an attempt to summarize and identify the important points made during the discussions. The chairman opened the meeting with the statement "We will produce, as best we can, a listing and summary of what is going on in Southern California and Arizona in universities, government, aerospace industry, oil companies, etc., in relation to education in remote sensing of the environment."

Table 1 is compiled from (1) descriptions, narrations and discussion of the four panel members and several members of the audience; (2) courses listed by David L. Nealey in "Remote Sensing/Photogrammetry Education in the U.S. & Canada" published in the March 1977 issue of Photogrammetric Engineering and Remote Sensing; and (3) a search by the panel chairman of available 1978-79 catalogues from Southern California's universities, colleges and two-year colleges. The list is probably not complete and may contain errors in course number, units or title. The panel chairman takes full responsibility and apologizes to any individuals or departments omitted. The impression one gets, after looking at scores of catalogues and hundreds of course listings, is that Southern California and Arizona are well represented in the teaching of and educational activities related to remote sensing of the environment.

TABLE 1.- REMOTE SENSING/PHOTOGRAMMETRY AND RELATED COURSES AT INSTITUTIONS IN ARIZONA AND SOUTHERN CALIFORNIA

LEGEND

RS - Remote Sensing
RSr - Remote Sensing related
PI - Photo-Interpretation
PIr - Photo-Interpretation related
PG - Photogrammetry
PGr - Photogrammetry related
MPI - Map & Photo-Interpretation
PGe - Photogeology
AG - Astrogeology
SD - Systems Design
IP - Image Processing
OP - Optics

ARIZONA

1 Univ. of Arizona

Dept. of Civil Eng.
#254 Photogrammetry (PG)
3 Sem. hrs. UGrad/Grad

Dept. of Geography and Area Development
#298 Geographical Applications of
Remote Sensing (RS)

Dept. of Geosciences
#207 Photogeology (PGe)
3 Sem. hrs. UGrad/Grad
#207 Applied Multispectral Imagery (RS)
2 Sem. hrs. Grad

Dept. of Watershed Mgt.
#220a Photogrammetry (PG)
2 Sem. hrs. UGrad/Grad
#220b Photointerpretation (PI)
2 Sem. hrs. UGrad/Grad
#298b Applications of Remote Sensing
and Computer Mapping (RS)
UGrad/Grad

Dept. of Optical Sciences
#230 Introduction to Remote Sensing (RS)
#231 Photographic Remote Sensing (RS)
3 Sem. hrs.
#233 Photo-Electronic Imaging
Devices (SD)
3 Sem. hrs.
#235 Automatic Information Extraction
and Classification (IP)
3 Sem. hrs.
#238 Radiometry (RS)
3 Sem. hrs.
#239 Infrared Techniques (SD)
3 Sem. hrs.

Dept. of Optical Sciences continued...

#266 Optical Detectors (SD)
3 Sem. hrs.
#267 Photographic Processes (OP)
3 Sem hrs.
#267L Photographic Processes
Laboratory (OP)
1 Sem. hr.
#332 Optical Properties of the
Atmosphere and Ocean (OP)

Dept. of Atmospheric Sciences
#356a-356b Atmospheric Optics and
Radiation (OP)
3 Sem. hrs.
#361 Radar Meteorology (RS)
3 Sem. hrs.
#385 Principles of Atmospheric Remote
Sensing (RS)
3 Sem. hrs.

[1] Arizona State University

Dept. of Geography
#575 Geographic Applications of Remote
Sensing (RS)
3 Sem. hrs.

[1] Northern Arizona University

Dept. of Engineering
#330 Photogrammetry (PG)
3 Sem. hrs.

Dept. of Geography
#418 Remote Sensing Techniques (RS)
4 Sem hrs.
#419 Remote Sensing Techniques (RS)
#430 Remote Sensing
Techniques-Methodology (RS)
2 Sem. hrs. Trips

Dept. of Forestry
#524 Airphoto Interp (PI)
3 Sem. hrs. Grad

[1] Phoenix College

Dept. of Engr. Science
#242 Topographical Surveying (PG)
3 Sem. hrs.

Dept. of Civil Technology
#205 Introduction to
Photogrammetry (PG)
3 Sem. hrs.
#248 Geodetic Surveying
3 Sem. hrs.

[1] Central Arizona College - Coolidge

Dept. of Civil Technology
#220 Photogrammetry (PG)
3 Hrs. UGrad

[1] Arizona College of Technology

Dept. of Civil Eng. Tech.
#202 Surveying II (PGr)
4 Sem. hrs.

SOUTHERN CALIFORNIA

[1] Allan Hancock College - Santa Maria

Dept. of Engineering
#7B Surveying (PGr)
3 Units Trips

California State Polytechnics, San Luis Obispo

Natural Resource Management
#405 Applied Resource Analysis (RSr)
4 Qtr. hrs. UGrad

California State Polytechnic Univ., Pomona

Dept. of Geography
#310 The Earth from Space (PI)
4 Qtr. hrs. UGrad
#410 Photographic Remote Sensing (RS)
4 Qtr. hrs. UGrad

California State University - Fullerton

Dept. of Geography
#280 Interpretation of Maps and (MPI)
Aerial Photos
1 Sem. hr. UGrad
#384 Airphoto and Image Interpretation (PI)
3 sem. hrs. UGrad/Grad

California State University - Long Beach

Civil Engineering
#427 Engineering Photogrammetry (PG)
3 Sem. hrs. UGrad

Dept. of Geography
#483 Aerial Photo Interpretation
and Remote Sensing (PI,RS)
3 Sem hrs. UGrad/Grad

Dept. of Geology
Aerial Photo Interpretation
Photogeology and Geomorphology
(To be introduced in 1979) UGrad/Grad

California State University - Los Angeles

Dept. of Geography
#465 Air Photo Interpretation (PI)
4 Qtr. hrs. UGrad/Grad
#466 Remote Sensing of the Environment (RS)
4 Qtr. hrs. UGrad/Grad

Geological Sciences
#483 Photogeology (PGe)
4 Qtr. hrs. UGrad/Grad

California State Univ. at Northridge

Dept. of Geosciences
#331 Photogeology (PGe)
1 Sem. hr. UGrad Trips

Dept. of Geography
#307 Air Photo Interpretation (PI)
3 Sem. hrs. UGrad
#407 Remote Sensing (RS)
3 Sem. hrs. UGrad/Grad

California State University - San Diego

Dept. of Geography
#382 Use and Interpretation of (PI)
Aerial Photographs
3 Sem. hrs. UGrad

California State University - San Diego (continued...)

Dept. of Geography (continued...)

#587 Remote Sensing of the Environment (RS)
3 Sem. hrs. UGrad/Grad
#588 Adv. Remote Sensing of the Environment (RS)
3 Sem. hrs. UGrad/Grad
#687 Seminar in Remote Sensing of the Environment (RS)
3 Sem. hrs. Grad

Geological Sciences
#505 Photogeology (PGe)
3 Sem. hrs. UGrad/Grad Trips

[1] Foothill College - Los Altos Hills

Dept. of Geology
#14 Map Reading and Aerial Photo Interp. (MPI)
2 Qtr. Hrs.
Planetary Geology (AG)
3 Qtr. hrs. UGrad Trips

[1] Fullerton College

Dept. of Civil Eng. Technology
#2 Aerial Photo Interp. (PI)
3 Sem. hrs. UGrad

Dept. of Earth Sciences
Planetary Geology (AG)
3 Sem. hrs. UGrad

[1] Pasadena City College

Dept. of Eng. & Tech.
#170 Photogrammetry (PG)
6 Sem. hrs. UGrad Trips Evening
#170A Photogrammetry (PG)
3 Sem. hrs. UGrad Trips
#170B Photogrammetry (PG)
3 Sem. hrs. UGrad
#170C Photogrammetry (PG)
4 Sem. hrs. UGrad
#170D Photogrammetry (PG)

[1] Pomona College

Dept. of Geology
Planetary Geology (AG)
4 Sem. hrs. UGrad Trips

San Bernardino Valley College

Dept. of Geography
#134 Remote Sensing of the Environment (RS)
3 Sem. hrs. UGrad
#136 Photogrammetry (PG)
3 Sem. hrs. UGrad
#137 Photogrammetry (PG)
3 Sem. hrs. UGrad

University of California - Los Angeles

Dept. of Geography
#169 The Earth from Above (MPI)
4 Qtr. hrs. UGrad
#269 Remote Sensing of the Environment (RS)
4 Qtr. hrs. UGrad/Grad

Dept. of Earth and Space Sciences
#150 Remote Sensing for Earth Sciences (RS)
4 Qtr. hrs. UGrad/Grad Trips Evening
#204 Advanced Remote Sensing (RS)
4 Qtr. hrs. UGrad/Grad

Univ. of California - Riverside

Dept. of Earth Sciences
(Geography Program)
#4 The Earth From Space (PI)
4 Qtr. hrs. UGrad
#158 Remote Sensing of the (RS)
Environment
4 Qtr. hrs. UGrad/Grad

Univ. of California - Santa Barbara

Dept. of Geography
#115A Geographic Photo Interpretation (PI)
#115B Geographic Photo Interpretation
and Remote Sensing Techniques (PI,RS)
#115C Intermediate Geographic Remote
Sensing Techniques (RS)
4 Qtr. hrs. (each) UGrad/Grad
#215 Seminar in Remote Sensing (RS)
#216 Seminar in Remote Sensing (RSr)
Instrumentation and Software
4 Qtr. hrs. (each) Grad

Univ. of California - Santa Barbara (continued...)

Dept. of Electrical Engineering and
Computer Science
#178 Fundamentals of Computer Image Processing (IP)
3 Qtr. hrs. UGrad/Grad
#278 Computer Image Processing (IP)
3 Qtr. hrs. Grad

University of Southern California

Dept. of Geology
Remote Sensing for Earth Scientists (RS)
3 Sem. hrs. Grad Trips Evening

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[1] Listed in Nealey, David L., "Remote Sensing/Photogrammetry Education in the U.S. & Canada," Photogrammetric Engineering and Remote Sensing, Journal of the American Society of Photogrammetry, Vol. XLIII, No. 3, March 1979, pp. 263-265.

In addition to educational facilities and courses, discussion of potential employers and sources of remote sensing material and products was ensued. A consensus of panel members and audience participants was that most employers seek graduates well founded in disciplines before they seek graduates trained in remote sensing. Well educated students that have experience in remote sensing as well as a strong discipline background are often more successful in obtaining a job. It is impossible to discover or list all the potential employees or all the known employer's addresses, phone numbers, person to contact or what the agency or firm might be seeking at any one time. A review of the tapes recorded at the workshop produced the following list of public agencies and private firms known to have employed graduates with training in remote sensing of the environment.

Name	City
Jet Propulsion Lab	Pasadena
Bureau of Land Management	Riverside
ESRI	Redlands
AIS	Crestline
San Bernardino County	San Bernardino
Riverside County	Riverside
Los Angeles County	Los Angeles
Orange County	Santa Ana
Ventura County	Ventura
San Diego County	San Diego
Hennings, Durham and Richardson	Santa Barbara
Oceanographic Services, Inc.	Santa Barbara
General Research Corporation	Santa Barbara
General Electric Tempo	Santa Barbara
Humans Factors Research	Santa Barbara
Eskatech	Huntington Beach
Tetratech	Pasadena
Aerojet General	West Covina
Calif. Dept. of Water Resources	Los Angeles
Lockheed Electronics	Houston, TE

Name	City
General Electric	Beltsville, MY
Earth Satellite Corp.	Berkeley and Washington D.C.
McDonnell Douglas	Worldwide
Mobil Oil	Worldwide
Dames and Moore	Worldwide
Chevron Research	Worldwide
Exxon	Worldwide
Converse, Davis and Fugro	Worldwide
Goodyear	Phoenix
USGS, Water Resources	Tucson
USGS, Conservation	Palo Alto
ARIS (Arizona Regional Information System)	Phoenix
Motorola	Phoenix
USGS	Flagstaff
NASA	Ames
NASA	JSC
NASA	Goddard

To obtain imagery, data and various teaching materials within the southern California/Arizona region is a matter of contacts and "seek and search". The members of the panel are willing to act in certain instances to assist and direct inquiries. However, to list the persons at various government agencies, universities, research labs or private industry without their prior approval is an imposition the panel chairman will not tolerate.

The Northern California
Hawaii Regional Academic Workshop
CORSE '78

Lawrence Fox III*
Humboldt State University
Arcata, California 95521

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*Other panel members are listed on page 305.

INTRODUCTION

The session began with twenty minute presentations by L. Fox, R. N. Colwell and E. Wingert on remote sensing philosophy and curriculum at Humboldt State University, University of California at Berkeley, and University of Hawaii respectively. An open exchange session followed discussing the Service role of the University in dispensing photos, maps and supplies; sources of free or inexpensive imagery and equipment; philosophical considerations in offering a remote sensing degree; the role of NASA in remote sensing education at the University level; and, finally cooperative strategies for California campuses in remote sensing education.

FORMAL PRESENTATIONS

Humboldt

L. Fox emphasized that remote sensing is approached from an interdisciplinary point of view. A two unit (quarter) introductory remote sensing course serves as the primary building block and each discipline has a variety of follow-on courses.

In Forestry, a four unit course on air photo interpretation gives the students the background necessary to use low altitude photos in the forest environment. A graduate course exposes students to the advanced principles of remote sensing from reflectance theory and thermal emission to digital data analysis. Air photo interpretation is also used as a data source in other forest measurement and forest management courses in the department.

The Natural Resources Program contains a basic photo interpretation course and the faculty is considering the addition of an advanced remote sensing/inventory design course. Remote sensing data products are also used in other natural resource interpretation courses.

In Geography the faculty is developing a land-use analysis/remote sensing course. The Geology department teaches a remote sensing image interpretation course. Remote sensing is thoroughly integrated into the programs of both of these departments. Many concepts of geology and geography are more easily presented and understood from the aerial perspective.

U.C. Berkeley

R. N. Colwell first outlined the basic undergraduate program in remote sensing and then commented on his personal philosophy in regard to remote sensing education. All Berkeley forestry students spend a short time with photos at forestry summer camp. Only those interested take a four unit course in remote sensing in natural resources. The course emphasizes basic air photo interpretation with comparison to Forest Service mapping for evaluating student work. A graduate seminar is also taught in a flexible style to meet the varying needs of graduate students.

Beyond these three courses, remote sensing at Berkeley is presented only in the context of the Space Sciences Laboratory research program. Colwell emphasized that this approach of "learn by doing" or "on the job training" has worked very well and many Berkeley graduates are currently in responsible positions in Government and Industry.

U. Hawaii

E. Wingert summarized the three courses offered at the graduate level at Hawaii: a basic photogrammetry class, a course in image interpretation and a seminar course with varying subject matter. Efforts are being made to expand the program so that "so much ground will not have to be covered by so few classes." Research is developing in thermal sensing, detailed ecological mapping, archeology and water resources. Hawaii is a small enough geographical area that low altitude photography and ground surveys usually meet the information needs.

The group expressed special interest in locating and mapping the intrusion of fresh water into salt water in the coastal areas. However, Wingert reported that this area of research is not now active in Hawaii. He indicated that cooperation with Federal and State agencies on remote sensing projects was virtually nonexistent in Hawaii, however, the potential was there.

OPEN SESSION

University Service Role - Cal State Chico

Chuck Nelson from Chico State is organizing a remote sensing lab within the library complex. The lab is public service oriented, an extension of the map library, and contains aerial photography and "Vari-scan" enlargers. The lab has been received very well by the public, especially farmers and ranchers in the Central Valley area. There is also considerable interest within the campus with ten departments showing interest. Chuck finds himself giving many guest lectures for other instructors interested in remote sensing.

Sources of Supplies

A lengthy discussion centered on the sources of free/low-cost imagery and equipment. Of special note was:

- * The Water Resources Board in Red Bluff. Color 35-mm slides from light aircraft
- * The Coastal Commission. General aerial photography
- * The California State Surplus Warehouse. Several items of equipment, sometimes photo interpretation equipment
- * U.S. Air Force. Surplus photo equipment

Educational Philosophy

Generally it was felt that a program should be offered at the graduate level that combined remote sensing technology with an area of application. Approximately 6-12 units in remote sensing to serve as an introduction with the more advanced remote sensing skills being learned through experience. R. N. Colwell felt that a masters degree in "pure" remote sensing was not useful. Several people suggested that other departments on a campus should support a remote sensing program. Physics, Mathematics and Biology might provide cooperative support for example. Joseph Leeper (Geography, Humboldt State) pointed out that many science departments are so overburdened in their service role to general education that they would be unable to support remote sensing programs.

The problem of securing excellent instructors was brought up. The idea of part-time people, borrowed from industry was considered. This concept is working at the University of Michigan.

R. N. Colwell stressed the fact that many campuses need to offer remote sensing rather than the few major centers, so that the discipline strengths of many schools might round out the educational process.

NASA

Ben Padrick (NASA Ames) pointed out that NASA would like to be out of the education function in remote sensing and support Colleges and Universities already expert in educational theory. In the near term, NASA will be very limited by funds. NASA is committed (long term) to the support of universities in order to best integrate remote sensing within disciplines. NASA feels that the greatest hope for operational use of their vehicles rests with this philosophy.

In response to NASA, many pointed out that hardware (especially computer equipment) was a major road block to the integration of remote sensing into College curricula. People seemed to agree that compatible equipment and software was a key to solving this problem. Wingert mentioned a lack of hard copy output products as a major barrier and the lack of information on NASA programs was very disturbing. Another problem raised by Wingert was that most NASA software is written for large memory, mainframe computers. Many smaller Universities have mini-computer systems that have time available for Landsat digital analysis. The future availability of NASA, ERL (Slidell, CA) software written for mini-computers should help alleviate this problem.

The lack of color CRT's was not seen as a major problem since most felt that standard line printer output was more instructive as to the digital nature of the data.

Chuck Nelson (Chico) was very interested in the possiblity of a time sharing arrangement with NASA Ames by remote terminal. This might allow a smaller University to enter into digital processing without an exorbitant equipment expenditure.

Cooperative Strategy

Much excitement was expressed concerning the cooperation of several campuses expecially in sharing field trips. Colwell noted that there are two test sites which have been studied thoroughly and that the Berkeley people would be happy to host a field trip. L. Fox also offered to host a field trip in the Trinity River area. Mendocino was also mentioned as an area to visit since Berkeley is just finishing a fuels management, Landsat inventory in that area.

Finally Colwell talked about the possibility of the California ASVT proposal being funded. This would be the first step in combining the collective expertise of various users of remote sensing. This effort could also help to unify the educational effort in California.

Panel members:

Robert N. Colwell, University of California, Berkeley
Everett Wingert, University of Hawaii
Sen-dou Chang, University of Hawaii

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Conference on Remote Sensing Educators

CORSE - 78

26-30th June, 1978 Stanford University, California

Report on Regional Workshop Three: Central States, Nevada, Utah, Colorado, Wyoming

Chairman Jack D. Ives, INSTAAR, University of Colorado

James Smith, Colorado State University

Lawrence M. Ostresh, University of Wyoming

Merrill Ridd, University of Utah

Charles Smith, Air Force Academy

The workshop was held in Room 270 of the Tresidder Memorial Union, 8:30 to 12:00 noon, June 28th, 1978. Ten to twelve participants remained with the workshop throughout the morning, the more active being Robert D. Rudd, University of Denver, James Smith, Colorado State University, Eugene Maxwell, Colorado State University, Joseph Linz, Jr., University of Nevada, and Donald G. Moore, South Dakota University. Dale Lumb, Chief, Technology Applications Branch, NASA Ames, joined the discussion during the second half of the morning.

INTRODUCTION

The first thirty minutes was devoted to discussing what was conceived as the purpose of the workshop. Topics ranged from problems of university education in all aspects of remote sensing, to applications, to research, and to interface problems between university groups themselves, and between the universities as a unit, state agencies and NASA and other federal agencies.

The difficulties facing remote sensing as an independent discipline viz its frequent use as a splintered technology amongst a group of traditional academic disciplines was also touched upon. Examples of success of specific projects, and of unrealized opportunities were also introduced. It was finally decided to concentrate on problems and opportunities relating to the furtherance of effective working relations amongst the universities, state agencies and NASA. A few principal points emerged and these are amplified, with associated recommendations as the body of this report.

PRINCIPAL POINTS

1. It is assumed that one of NASA's long-range goals is the transfer of technology to all levels of potential user groups, and that within the context of CORSE - 78, state agencies comprise a substantial proportion of such user groups. With this in mind there is need for recognition that effective technology transfer will heavily depend upon a three-legged tripod representing NASA, the universities and the state agencies. Maintenance of all three bases is essential. While we perceived that the current provision of short courses by NASA for state agency staff is both useful and financially desirable in terms of short-term budgeting, the long-term goal is better served by a considerable strengthening of the universities in terms of their ability to (a) keep fully abreast with the developing edge of remote sensing technology, (b) to relay this through a variety of education programs to state agency staff and (c) to provide the state agencies with new fully-trained staff as finished graduate students as state recruiting proceeds over a long period of time. These latter university training functions do not necessarily have to compete with NASA's provision of short courses directly to state agency staff. In fact the two approaches should be essentially

complementary since we recognize the necessity of introducing senior state management levels to the nature and opportunities of remote sensing technology.

2. It was emphasized that there is a need and an opportunity for greatly fostering instruction in computer-assisted analysis of remote sensing data. A possible approach to a mechanism for this can be best described by using the 1960's NSF approach to computers and computer science as an analogue. Thus, at that time, NSF attacked the problem of the need to integrate the then new computer technology into the educational system through special grants for both programs and equipment to particular university centers. It is recommended that NASA play a similar role with respect to remote sensing technology. This can be divided into provisions of funding for development in three somewhat different, but related areas:

a) instructional
b) research utilization
c) operational

The first, instructional, is considered as a unique university function and is to be acheived most economically and efficiently within a university setting. The third, operational, should be an outgrowth of (a) and (b), and should pay for itself. The second, research utilization, lies somewhat in between and will frequently require start-up funding.

Within the Central States region it is clearly seen that there is a great disparity amongst universities in terms of their currency and level of activity in remote sensing technology instruction and research. The Colorado Front Range corridor, as one example, represents the major center of both university activity and potential and actual state and federal agency user groups. But even here, CSU holds a preeminent position. Similar comparisons could be made for other areas. Thus it is recommended that existing centers of strength be further strengthened through NASA funding, particularly in the area of computer-assisted analysis of remote sensing imagery. Thus an effective heirarchy could be established with regional lead centers providing instructional packages and computer terminals, as well as on-site specialized courses, for other university centers, as well as direct training for state agency staff. One particular mode that was discussed at some length at the workshop was the potential utilization of the ARPA Network as an instructional resource. A large number of computer-assisted analysis programs have been implemented and are maintained by NASA-Ames. Within specified machine resource limits, use of these programs could greatly foster the general dissimination of base level expertise and conformity. Any such development should be dependent upon the provision of a degree of matching fund support either directly by the relevant state agency, or indirectly by state funding to the relevant university. This approach, of course, should in no way preclude the continuity of existing teaching and research in remote sensing at other levels in the heirarchy; rather it should serve as a stimulant.

3. A serious problem facing current university remote sensing instructional and research centers is a shortage of funds in the areas of equipment maintenance, technical staff, travel and communications. This problem will grow with the increasing success of further technology transfer. Expensive equipment, provided through a grant, can quickly require extensive repair and maintenance, for instance, which a university administration cannot, or will not, cover. Training and maintenance of sophisticated technician staff on short-term research grant and contract funds can become a nightmare for center directors. Travel to a major scientific conference is usually easily provided for while it proves impossible to obtain modest reimbursement for short-distance travel to, for instance, a state capital.

What is required here is a mechanism for low-key, modest, but long-term, flexible nuts-and-bolts funding to particular university centers.

4. WRAP is urged to take a more active role in communication with university centers and in influencing the relationships between university centers themselves, and amongst them, on the one hand, and state agencies, on the other. Better dissemination of information on research funding opportunities, and active support of programs that would be advantageous to the instruction of graduate students, is required. NASA can influence, for better or for worse, the relationships between university centers and state agencies. Through a careful and diplomatic approach NASA has the opportunity of helping to effect a state of interdependency between the two groups.

RESPONSE TO FORMAL QUESTIONS

1. A specific degree-level curriculum in remote sensing should not be developed. Strengthening of the traditional approach would seem desirable. A degree program would run the risk of widening an already existing gulf between remote sensing experts and user disciplines. A strengthening and modification of the traditional approach has already been covered indirectly in the preceeding section. Restated here, this could involve identification of existing lead centers and the development of state/regional hierarchies whereby less well-equipped centers can be united to the regional lead center or centers, thereby capitalizing on the provision of major equipment. Major equipment would especially include computer-aided imagery analysis both in an operational and educational sense.

2. While the answer to question one precludes an answer to this question, it should be emphasized that traditional academic departments be heavily encouraged to embrace remote sensing education (and graduate level research) as a vital part of the curriculum of each relevant discipline.

3. Further infusion of the concepts of remote sensing and its advantages

to the relevant managers, individually, and agencies. Such could be accelerated by more short courses and by additional effective demonstrations through specific applications. As one example INSTAAR has in preparation a multicolored map (1:24.000) of natural hazards of a USGS quadrangle (Front Range, Indian Peaks Wilderness Area). Natural hazard (geologic hazard) mapping is a well recognized need in Colorado following passage of COLO House Bill 1041 in 1974, yet still no standardized mapping legend has been adopted. With production of the proposed map, a manual will be prepared describing (a) the production process and cost-benefit, (b) the importance of completing a state-wide mapping project and of expanding this to adjacent states and (c) the need for standardization of legends. This will be printed for distribution to state agencies, legislators, insurance companies, banks and finance houses and the public. In this case we will be stressing the importance of the NASA color IR imagery upon which the mapping was based. It is part of INSTAAR's on-going NASA-PY project (Grant No. NGL-06-003-200), monitor, Mr. Joseph Vitale. It is but one example of an approach to increasing awareness both of managers and public. Other examples could be added.

a) Increasing awareness, communications and collaboration on specific research and instructional projects between state agencies, university centers and NASA;

b) Development of firm but diplomatic initiatives by NASA to achieve the above;

c) Increased awareness of the opportunities afforded by the technology available. This will result from progressive recruiting into the employer sector of young professionals with remote sensing expertise and through familiarization short courses for the senior staff; the two are complementary.

I wonder if we need to answer questions 5, 6 and 7 specifically? Question 8 seems well answered under the preceeding section "principal points."

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NORTHWESTERN ACADEMIC WORKSHOP ON REMOTE SENSING EDUCATION

Richard D. Shinn, Chairman*

Department of Urban Planning
University of Washington, Seattle

Introduction

The tasks we face as educators in the process of assisting and assimilating the emergence of a new technology and a supporting discipline are immense. We have seen several years of glamorous research and development associated with the Landsats. Remote sensing has been around as long as aerial photography, but not until recently have we been faced with such big questions of education. It has been suggested that our responsibility for education springs from the basements of ivory towers and spreads throughout higher education, down into the secondary schools and even to elementary school education. Should everyone know about remote sensing ?

It is not my intended role here to be either facetious or negative. Rather, we are asked to put remote sensing education into perspective in our four northwestern states - Alaska, Idaho, Oregon and Washington. The particulars of that task are overwhelming and one half day of workshop can not pretend to answer all the questions asked of us.

A complete inventory of the higher educational institutions in our region has been requested. That inventory should seek the mission of each constituent unit involved in the research, public service and/or teaching of remote sensing. The task requires a search of institutions by expected disciplines: civil engineering, forestry, geography and geology. Also, we must add the unexpected** - land studies, environmental studies, planning and others. It is estimated that over sixty (60) of these units exist in our four states in as many universities, state colleges and community colleges.

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*Other panel members are listed on page 334.

The panel has made a preliminary effort at identifying these units from contacts in our own locale. The lists are not complete, and it would be unfair to those left off to consider them more than preliminary. A strict definition of remote sensing as a technology would make the inventory an easier task, but it would be self-defeating if we eliminated all those disciplines teaching applications of remote sensing.

A few institutions are named in national directories with similar inventory purposes (ref.1). In Alaska, there is the Geophysical Institute at the University of Alaska, Fairbanks. In Idaho, the Departments of Forestry, Geography and Geology each have a program. In Oregon, there is the Environmental Remote Sensing Applications Laboratory at Oregon State University in Corvallis. The Department of Geography at the University of Oregon in Eugene offers remote sensing instruction. Similar instruction is offered in the Soils Department at Washington State University in Pullman. There is the Remote Sensing Applications Laboratory at the University of Washington

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**These are unexpected for two reasons: (1) they are not commonly found in all institutions; and (2) they are not always teaching remote sensing.

in Seattle. Also, teaching of remote sensing is available in the Departments of Civil Engineering, Forest Resources, Geography, Geology and Urban Planning at the University of Washington.

Those named are well represented on this panel by Paula Krebs, University of Alaska, Fairbanks; Barry Schrumpf, Oregon State University, Corvallis; Joseph Ulliman, University of Idaho, Moscow; and Bruce Frazier, Washington State University, Pullman. Also, the workshop has present a broader representation of those institutions named and others.

A second major task is to estimate the job market for remote sensing graduates, locally and nationally. The desire of this workshop is that we identify employers in industry, academia and government. Such a statement of needs could be used to justify courses, facilities, degree programs and teaching staff.

Another inventory has been requested that covers the regional sources assisting the teaching of remote sensing. Who assists the teaching staff ? Who provides data products ? Are these industrial cooperators or governmental cooperators ? Are documented applications of remote sensing available for teaching materials ?

All of these questions were to be answered precisely for you in a thirty minute paper, prepared jointly by the panel with long distance calls for which no toll free numbers were provided. We have defaulted in this higher mission objective. However, we have not abrogated our responsibilities. What we have done in preparation is stage setting for the higher order task, and we endorse its merits.

In addition to discussing these three big questions:

1. Northwestern higher educational institutions in research, public service and teaching of remote sensing.
2. Northwestern and national job market for remote sensing graduates in industry, academia and government.
3. Northwestern assistance from the industry and government for remote sensing educators.

We must proceed to discuss the following set of topics to complete our agenda:

4. Curriculum development.
5. Related course work.
6. Degree programs.
7. NASA involvement.
8. Student achievement.
9. Faculty qualifications.
10. Intercollegiate cooperation.
11. Remote Sensing Science Council's Role.
12. Recommendations for CORSE-79.

These topics are suggested and should not be an inhibition to discussing other interesting topics related to remote sensing education. With this lengthy introduction, the stage is set for the discussion of the twelve topics listed. My statements will often be opinions, but where it is possible, I have attempted to recall and to estimate accurately the dimensions of the tasks posed. More importantly, it is the definition of issues that I wish to set forth now.

Who's Who in Northwestern Remote Sensing Education ?

The purpose served in identifying the particular involvements in regional, remote sensing education is to aid the many who are unacquainted with the small units and more often the individuals teaching in our institutions. A reputation survey is out of order and it would be a deadly instrument which we should oppose. My experience chairing the University Advisory Committee for the Land Resources Inventory and Demonstration Project of the Pacific Northwest Regional Commission revealed that each member and alternate had a special contribution to make from different disciplinary and methodological perspectives. As a whole, the group was complementary and gained some synergy. We all gained from a better knowledge of each other's efforts.

In particular, identification of special classes, special research skills, special equipment and special people is something we all would relish. It would facilitate advancement of remote sensing education, if we each were committed to adding to our preliminary inventories and to monitoring its upkeep.

Sizing Up the Northwestern Job Market in Remote Sensing

A monumental effort has been made by researchers in Phase IV of the Land Resources Inventory Demonstration Project (ref.2). The Westerlund and Wilson study of user needs shows the demand for remote sensing operations in the involved state and local planning and resource management agencies (ref.3). They have identified three types of demand: (1) All Functions; (2) Priority Functions; and (3) Priority One Functions Only. It is the Priority One, data processing demand that I am using in the following estimate of the annual workload for three states. If these agencies can attain their high priority objectives, we can make estimates of jobs generated.

The following are assumptions:

1. One Landsat scene is a basic unit.
2. $250,000 is the total cost for land cover in a Landsat scene that is geometrically corrected and verified at 85% accuracy for the classification. Multi-temporal analysis and two-stage classifications are assumed.
3. One third of the effort is data processing and product production. It is assumed that these have equal parts.
4. One third of the effort is photointerpretation and field surveys to select training fields and to verify classification. It is assumed that photo interpretation and field surveys are equal parts.
5. One third of the effort is administrative overhead.
6. Jobs generated:

Person Years	Remote Sensing Specialties
1.0	photo interpreter
1.0	resource specialist
.5	cartographer
.5	data processor
.5	statistician
.5	remote sensing specialist
4.0	

These numbers are recent and competitive. They can be used directly to translate the workload from the following table:

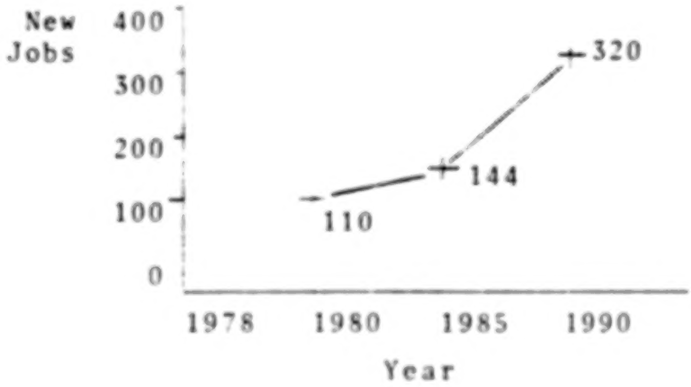
Landsat Data Processing in Idaho, Oregon and Washington:

State	All Functions	Priority Functions	Priority One Functions Only
	Equivalent Scene Area Per Year		
Idaho	25+	15.9	12.3
Oregon	30+	11.1	6.6
Washington	25+	9.0	7.6
Total	80+	36.0	26.5

Source: Westerlund and Wilson (ref.3), pages 42a and b.

Assuming Priority One Functions Only for 1980, Priority Functions for 1985 and All Functions for 1990, a projection of job demand can be made:

Forecast of New Jobs in Remote Sensing for the Northwest States of Idaho, Oregon and Washington: 1980, 1985 and 1990.



At the present time 100 individuals have been listed as participants in state and local planning agencies in the three states (ref. 4). Only a fraction of that number are full-time, however. The Priority One Functions Only represent at least a twofold increase in digital analysis for land cover at the current level of effort. The curve in the projection represents the beginnings of a growth curve, which is increasing at an increasing rate. It is also the most difficult to forecast, which can encourage a position on growth that is too conservative.

This forecast suggests a northwest job market for 1985 graduates as follows:

1985 Job Increase in Remote Sensing in Idaho, Oregon and Washington:

Specialty	Number
-photointerpreters	36
-resource specialists	36
-cartographers	18
-data processors	18
-statisticians	18
-remote sensing specialists	18
	144

An old adage is, "If you believe a forecast, it will happen". It is not our purpose to oversell job opportunities to potential students. Rather, we need to anticipate the growth in state and local governmental processing of Landsat data. Also, industry use of Landsat, increased use of conventional methods of remote sensing and Alaska are not included in this forecast. Nor can the national job market be assumed as twelve times these forecasts, because utilization of Landsat has been promoted in the Northwest by the National Aeronautics and Space Administration (NASA) and the United States Geological Survey (USGS). Nonetheless, the job market can be expected to grow and an educational demand will increase for universities and state colleges in the northwestern states.

Who Is There to Help ?

Educators look for documented studies, operations specialists, data resources, data products and facilities, when they seek assistance from government and industry in applied technology. Landsat applications have not advanced to the stage where either industry or state and local government offers more than elementary assistance. We are still relying upon NASA and USGS to provide technical assistance, data processing, data products, documents and facilities, even though it is in association with user agencies in most cases. Research and development has not been a priority in efforts involving user agencies. Demonstrations and potential operations have been the objectives of the northwest project.

The Regional Applications Program in NASA has a change of objectives in which the educational needs are prominent.† Industry is beginning to provide service on a competitive basis, which offers prospects for teaching materials and assistance. However, most companies are in no position to be benevolent to the educator without a data processing budget. Also, competition between educational units and industry is to be avoided. Research development, demonstration, and testing operations can all be within the public service role of education, but providing a regular service in operations of state and local government is consulting. A respectful relationship is imperative to developing a job market for students in industry and an industry benevolent to education.

As a matter of discussion in this workshop, we should identify the firms and agencies that can assist and would welcome educators. Our region does not havea major Landsat, data processing, equipment manufacturer. Thus, industry consists mainly of consulting firms.

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†Western Regional Application's Program is one of three programs and covers fourteen western states.

Where Are We Going In Remote Sensing Education ?

Nine topics were introduced for our consideration of educational development in remote sensing. Each of these topics with some definitions are offered here. Our task is to set goals and recommend actions related to these topics. Time will not permit either a consensus or a vote on any issue. Individually, we must begin by stating positions, which can be expected to result in a summary of contradictions. Nonetheless, identifying debatable issues in this set of topics is a worthwhile objective of our workshop.

Curriculum Development

Course development in remote sensing and remote sensing applications implies a relationship to a curriculum. It is assumed that a course or sequence of courses on remote sensing may exist in the curricula of several different disciplines. At the outset, remote sensing as a technology is distinguished from remote sensing applications such as forest management and land use planning.

Related Course Work

Courses in which one or more class sessions are devoted to remote sensing topics qualify as related course work. Also, there are courses like cartography and information systèms, which are valuable related course work. The two types of course work include a remote sensing orientation in courses and courses required by the "would be" remote sensing specialists.

Degree Programs

A full course of study leading to a Bachelor of Science, Master of Science or Doctor of Philosophy is a degree program. A full curriculum devoted to educating remote sensing specialists is not a popular idea among educators. Only 12.5% of the jobs generated in the preceding forecast was for remote sensing specialists. An accumulative set of eighteen jobs by 1985 in three states suggests the prospect that one small program in the Northwestern states would be all that could be justified by the forecast. The term remote sensing specialist in the forecasts includes both the technologists and the application specialists, which further complicates the issue of a single degree program (ref.5).

NASA Involvement

Most educators would agree that the time is not right to ask for funding of new programs or major program investments in higher education. The rising inflation costs are aggravated by declining enrollments. These conditions are expected to prevail into the 1980's. Both state universities and private institutions face this budget stress. NASA can help provide technical assistance, data processing, data products, documents and facilities to programs that are likely to produce graduates for the job market. Curriculum development would qualify several northwestern institutions for this comprehensive assistance. Related course work needs assistance with provision of teaching materials.

Student Achievement

Advancing students up a learning curve is predicated upon existence of curricula and faculty advisers. Skill acquisition is a measure of achievement in remote sensing. However, the skills are many and varied among the related disciplines that are valued in a remote sensing application. Sharp disagreements exist about what literacy is in this field. Must a student have any, part, or all of the following:

- physics of the reflectance of energies in the electromagnetic spectrum.
- map projections for the earth's surface
- cartography
- computer science
- statistics
- natural systems
- land use
- photointerpretation

Degree programs are an established way of assigning faculty responsibility for these questions. If we recommend less that degree programs in curricular development, we need to consider the way responsibility for student achievement is to be met.

Faculty Qualifications

Now, we ask the literacy question of the faculty. Should the list be longer ? Is a rigor in one of the above literacy items a requirement ? Must a faculty member have publications ? If so, in what journals ? Is a doctoral degree a requirement ?

These questions we ask of ourselves rather than our academic dean asking them of us. The questions imply affirmative answers from traditional expectations of faculty. Nothing suggests that remote sensing is any different than other applied technology fields. It is recognized that the involvement of individuals in remote sensing applications or technological developments make potential teachers that have a valuable contribution, however. All remote sensing educators need help in getting and maintaining pertinent and timely knowledge in this field.

Intercollegiate Cooperation

You can be sure remote sensing educators will cooperate when given the opportunity. Every institution named in this paper is fragile. That is to say, they are vulnerable by being: (1) funded with short-term grants; (2) they are small; or (3) they are viewed as novelties by their academic deans. Each of these vulnerabilities or combinations of them could be the basis for elimination by reorganization or budget cuts.

Cooperation is essential between higher educational units, because of the diversity of remote sensing technologies and applications of each technology to a wide variety of earth resource issues. No permutations are attempted here, but the point is clear that no remote sensing educator is an island.

Curriculum development as defined suggests intercollegiate cooperation is important within large universities, too. The task of educating a specialist without a designated degree program is possible only by cooperation.

Remote Sensing Science Council's Role

The Remote Sensing Science Council consists of one representative from each of the fourteen states in the Western Regional Applications Program. They have a mission, which is general enough to include all of the issues raised in this paper. We are asked to help them define their role in this organizing period. A University

Advisory Committee of six, headed by John Estes, University of California at Santa Barbara, has been assigned the organizing task with some funding. Barry Schrumpf from Oregon State University is the northwestern representative in this endeavor.

If we can establish priorities in this workshop, they should be sent with any other recommendations to the Remote Sensing Science Council for review. We should expect the Council to be advocates in our behalf who will pursue funding for remote sensing education.

Recommendations for CORSE-79

My opening comments lamented the fact that the job assigned to us could not be completed by CORSE-78. We need to set the objectives for this same workshop in CORSE-79. The job should be within our reach, and we should make individual contributions to the detail requested in the inventories.

Summary

Landsat demonstrations projects and assistance from USGS and NASA have enabled us to advance to a serious consideration of our collective goals as remote sensing educators. Several respectable yet fragile units have been formed in the four states - Alaska, Idaho, Oregon and Washington. Generation of new jobs in the region by Landsat data processing offers justification for curricular development in several institutions. However, no more than one new degree program for remote sensing specialists is justified by the forecasts of jobs. Six universities have shown a commitment to remote sensing education. Cooperation among educators is essential and likely to occur with financial assistance from NASA. Similar cooperation with industry and state and local government is necessary for remote sensing educators interested in applications of the technologies. An increased funding of research and development of remote sensing technologies is needed within the northwestern states.

High standards for student achievement and faculty qualifications are a responsibility to be assumed by our loose federation. Competition among ourselves and strict definitions of the field are discouraged. Rather, we must lend support to one another and pursue a complementary and synergistic educational enterprise in our region.

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COMMENTARY BY PANELISTS
(Addition to R.D. Shinn Paper CORSE '78 11-22-78)

Paula Krebs, University of Alaska in Fairbanks, explained the role of the Geophysics Institute in resources management, geology, geomorphology, land use and off shore ice as related to remote sensing applications. Demand from state agencies is large enough to justify 25-30 people in the next few years and double that by 2,000. The data base and resource people for aerial photointerpretation and Landsat data must be developed. The urgent need is for people and makes curriculum development essential.

Bruce Frazier, Washington State University, spoke to the grading of soil for forests lands by the Department of Natural Resources in the State of Washington as a leading application. The scope of the activity is 9 million acres of forest land. Fish and wildlife projects have included wetlands interpretation for habitat by remote sensing. Aerial applications of fertilizers and insecticides have people who are monitoring crops in color infrared to determine the condition of crops. These applications are not seen as job generators since people who are already there are being retrained to use new information. Forestry landscape architecture and soils science students at Washington State University are the clientele in curriculum development. Most of the community colleges have photointerpretation and/or map reading. Reference was made to the University of Washington by the moderator with names of individuals teaching remote sensing.

Joe Colcord, Civil Engineering at the University of Washington, listed several people and suggested that a broad definition of remote sensing would produce a set of courses like those of the University of Arizona.

Joe Ulliman, University of Idaho, began by explaining that their involvement in new remote sensing applications have been limited to the Land Resources Inventory and Demonstration Project of the Pacific Northwest Regional Commission. Several courses in forestry, geology, agriculture and cartography were listed. Agencies have to start using the remote sensing techniques before curricular development is meaningful to students.

Barry Schrumpf, Oregon State University, stated that 11 community colleges offering photointerpretation in the State of Oregon in forestry, civil engineering, geology, and geography three state colleges and two state universities are teaching remote sensing. Of 29 courses 4 mention remote sensing in their description. Only one course deals with digital processing. The goal has to be how to integrate the more recent remote sensing techniques with traditional remote sensing techniques into a valid teaching method. The students need both in their future jobs.

An Army National Guard unit in Salem has support capabilities for agencies around the State of Oregon. One thing that is really needed is a presentation of the advantages of Landsat data over conventional techniques by those who are involved in more recent applications.

His disagreement with the projections made in the body of the paper were the dominance of Landsat. He thinks the choice between conventional techniques and Landsat data analysis will reduce the number of jobs projected. Another point is that the Pacific Northwest Regional Commission's project was subsidized. If the subsidy continues, it is likely the projections will be realized. Only three state agencies in Oregon are known to have initiated projects with their own funds to do Landsat data analysis.

It is possible that the U.S. Forest Service will decide to adopt Landsat data analysis. If they do and they establish centers for users in multistate regions, the opportunities for applications and analysis by universities may dry up.

Charles Rosenfeld, Oregon State University, commented on the lack of conventional application in the Pacific Northwest Regional Commission Project. He attributed this lack to NASA's interest in seeing Landsat utilized. He went to enumerate the capabilities of the Army National Guard Unit in Oregon and several applications to demonstrate the interest of agencies remote sensing techniques other than Landsat.

Joe Colcord noted that there are no more than 10 firms in the private sector in the Pacific Northwest. Regardless of how many individuals they employ, each person would have to have considerable breadth of knowledge. As such, it does not offer a market and without federal funding several in the room would be looking for work.

R.J. Murray, Oregon State University, stated that Landsat is the only available digital data. Because of that we are using Landsat for a wide variety of applications.

Washington State Department of Natural Resources index of aerial photography and Landsat data was held up as a model for other states by Joe Colcord. It dates from 1949. Barry Schrumpf noted that the Department of Forestry in Oregon issues an annual index. Joe Ulliman pointed to Idaho Division of Land. Paula Krebs noted that the Bureau of Land Management and the EROS Program in the Geophysical Institute in Fairbanks are catalogued together. None of the other examples were considered equal to Washington DNR.

Panel members:

John Miller, University of Alaska
Barry Schrumpf, Oregon State University
Joseph Ulliman, University of Idaho
Bruce Frazier, Washington State University

Conference of Remote Sensing Educators

Northeastern States - Regional Academic Group

WORKSHOP REPORT

June 28, 1978

Prof. Frederick L. Gerlach
School of Forestry
University of Montana
Missoula, Montana

Dr. Joseph Ashley
Department of Earth Science
Montana State University
Bozeman, Montana

Dr. William A. Dando
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University of North Dakota
Grand Forks, North Dakota

Dr. Victor I. Myers
Remote Sensing Institute
South Dakota State University
Brookings, South Dakota

September 27, 1978

CONFERENCE OF REMOTE SENSING EDUCATORS

Northeastern States - Regional Academic Group

Workshop Report

Introduction

This paper reports the significant dialogue contained in the Northeastern States Regional Workshop on June 28, 1978 in Tresidder Memorial Union at Stanford University. The workshop panel included Frederick L. Gerlach (Chairman), William A. Dando, Joseph Ashley, and Victor I. Myers. In attendance and participating in the discussions were Drs. Donald Moore and Frederick Westin, South Dakota State University; Paul Seevers, University of Nebraska; Michael McCormick, WRAP liaison officer; and Robert M. Barlow, National Space Technology Laboratories.

The objectives of the workshop were stated as follows: 1) define remote sensing education problems having regional importance; 2) define problems of institutional or state importance; 3) assemble technical data relating to remote sensing educational services; 4) discuss and attempt to define the ways and means for solving regional problems; and 4) improve remote sensing education.

To facilitate the discussion, each panel member presented statements concerning conditions relative to their states and institutions. These statements follow in the order in which they were presented.

South Dakota State University (Brookings)

South Dakota State University is enhanced by the Remote Sensing Institute, which has been actively engaged in remote sensing research and the support of remote sensing education since 1969. The RSI was established for research purposes wherein the member researchers generally have teaching responsibilities and may have academic status. Under the direction of Professor Victor I. Myers, RSI provides both direct and indirect support to remote sensing within the university. The approach considers remote sensing as a tool within the traditional fields of agriculture, range science, soils, geography, hydrology, geology, engineering, etc. The primary academic support from RSI is directed toward graduate level education. Graduate degrees are pursued under the traditional departmental structure with RSI providing the students with fellowship funds, laboratory space, instruments, ongoing research problems, and the expert consultation of member researchers. The RSI recruits graduate students having capabilities and interests allied to current research projects. The RSI serves graduating students in their search for job opportunities. Accordingly, graduate degree candidates having some specialization in remote sensing are considered to have better than average employment opportunities.

A number of students in the university are employed by the RSI resulting in a significant level of technology transfer by association. For example, their student employees become aware of the wealth of information products available to the state through the RSI, the EROS Data Center, and other remote sensing facilities.

Undergraduate education is traditionally departmentally oriented. University courses available include photogrammetry, photo interpretation, remote sensing, and related supporting courses in computer science, pattern recognition, statistics, optics, photo sciences, and instrumentation. Significantly, Dr. Donald Moore has developed a formalized training program within the RSI utilizing visiting scientists and remote sensing consultants to train resource oriented remote sensing specialists.

Some problems do accrue from the organizational lines between the university and the RSI. Remote sensing education within the university would benefit if greater use were made of

RSI expertise in the development of curricula, course structure, and in teaching remote sensing courses. Relatedly, there is weak library facility support in the remote sensing area. The university library does not support this area well. RSI purchases books and periodicals to fulfill researchers' needs, and has established a substantial library within the Institute. The proximity and cooperation of the EROS Data Center tends to alleviate a library problem for research, but the problem remains for undergraduate and graduate education within the university.

In addition to the offerings at South Dakota State University, the School of Mines (Rapid City, South Dakota) now offers an experimental course in remote sensing (Geology 599) and a course in radar meteorology.

It is apparent that the RSI is a significant force in remote sensing education in South Dakota. It has worked with many federal and state agencies and foreign governments endeavoring to fulfill information needs through remote sensing. Its many research and development activities are tabulated in the CORSE-78 paper "Remote Sensing Research Activities Related to Academic Institutions" by V.I. Myers.

University of North Dakota (Grand Forks)

UNDIRS, the University of North Dakota Institute for Remote Sensing, was founded in 1975. Organizers were Dr. Roland D. Mower and Dr. Gary D. Johnson. The institute was organizationally structured within the Department of Geography. An executive committee was appointed by the Director (R.D. Mower). The committee members were Drs. K.D. Moe (Engineering), Associate Director;

William A. Dando (Geography), Executive Secretary and Department Chairman; E. Shubert (Biology); L. Clayton (Geology); J. Huppman (Engineering); S. Snyder (Anthropology); and G. Johnson (Geography). The executive committee drafted a constitution and by-laws, set goals and priorities, and determined the criteria for membership in the institute.

The Institute of Remote Sensing was announced to all federal, state, and local agencies and private companies within the State of North Dakota. About 40 members have been accepted into the UNDIRS. Grants have been received and some equipment purchased. Also, the university has allocated capital purchases for the UNDIRS.

Four new courses in remote sensing were approved. They are Introduction to Remote Sensing (Geography 275), Remote Sensing Applications and Analysis (Geography 475), Remote Sensing Systems (Engineering 375), and Seminar in Applied Remote Sensing (Geography 595). These new courses were combined with a series of existing courses to form a substantial offering of courses in the field of remote sensing. The existing courses are Graphics and Airphoto Interpretation (Geography 422), Seminar in Research and Writing (Geography 520), four Cartographic courses, a Map Interpretation course, Quantitative Application in Spatial Problems, Airphoto Interpretation for Geologists, and associated courses in mathematics, computer science, and engineering. UNDIRS believes these courses provide a sound undergraduate and graduate program in geography and all the related fields of those involved in the institute.

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CONFERENCE CLOSING CEREMONY 591 7/G8

APPENDIX 615 8/B7

Currently, six persons teaching in the program have had graduate training in remote sensing. They and their responsibilities are: Drs. R.D. Mower, Geography (UNDIRS Director, Land Use, Remote Sensing Education, and the Governor's Council); Gary D. Johnson, Geography (Agriculture, Environmental Problems, Land Use, Serving in the Governor's Office); R.D. Moe, Engineering (Engineering Hardware); F. Bein, Geography (Airphoto Interpretation, Selected Aspects of Graphic Analysis, Graph Theory, Computer Applications); Ken Langren, Geography (Computer Applications, Remote Sensing); and D. Clayton, Geology (Airphoto Interpretation in Geology).

Approximately 20 undergraduate and 10 graduate students. are majoring in some aspect of remote sensing in geography. Majors or minors in remote sensing in other departments are not known.

The UNDIRS has access to or has secured adequate equipment to develop a program. It does not have equipment of the nature necessary to expand its program. Probably not much additional equipment will be purchased, and development will probably rely on the university's computer. The equipment used most frequently includes a Richards Light Table, Bausch & Lomb Zoom Transferscope, Bausch & Lomb Stereoscopes, Zeiss Stereoscopes, Vara Scan Viewers, a complete cartographic laboratory, and a super photographic darkroom complete with a precision copy camera. The UNDIRS has an LSI ADM information display terminal, DEC and other type printers, field plotters, and other automated equipment. The terminals provide access to three computer systems including the IBM 370/148. A complete software library has been developed including standard packages, ORSER, and CMS-2. For research purposes, sensors, aerial camera, image acquisition, and processing are contracted.

Five major research projects are in progress. Recent publications include 2 books, 4 monographs, 12 professional papers, and 7 reviews. The Institute has sponsored two international symposiums (funded) and serves as a consultant for a number of foreign nations. Under the direction of R.D. Mower, the institute has achieved statewide acceptance and the support of the Governor.

The University of North Dakota has requested from the state a budget of $152,000 for the Institute of Remote Sensing. The UNDIRS has developed a different program which should be considered unique.

Montana State University (Bozeman)

The program of instruction in remote sensing at Montana State University includes four courses which may be generally described as photo interpretation. Presently, the offerings include a course in the Department of Earth Science, a course in Plant and Soil Sciences, and two courses in Civil Engineering. The Department of Earth Sciences was offering a course in photo interpretation in 1965. This was dropped in 1971 due to the transfer of a faculty member, and reinstated last year under the direction of Dr. Joseph Ashley. The course under the Department of Plant and Soil Science is the responsibility of Dr. Gerald Nielsen, and the program in Civil Engineering is directed by Dr. Donald Reichmuth.

The program status appears to be on the threshold of achieving continuity. The reinstated course under Earth Sciences emphasized physical geography, geology, and land use analysis utilizing airphoto interpretation techniques. This course is presently limited to 16 students. There is an indicated growth in student enrollment in all four courses, resulting in greater awareness within the three departments of the importance of remote sensing education. There are significant limitations of teaching equipment and materials. A clear need for administrative recognition of this problem was expressed. If greater continuity is to be achieved, resources need to be allocated to the purchase of equipment for teaching.

On the positive side, MSU was host to the NASA training session for the WRAP demonstration project trainees. This brought professionals and technicians from state agencies to the university for training in remote sensing. Several faculty members joined the trainee group, further emphasizing a need for an awareness of the importance of remote sensing education. Imagery used in this course, supplied by NASA, was given to the university for use in instruction. This supplies new Landsat imagery, high altitude U-2 imagery, and relatively recent 1:20,000 aerial photography for instructional purposes, resulting in partial solution of the materials problem.

Under the present program, it is possible for students to receive credit for two of the four courses offered.

One of the incentives for the Department of Earth Sciences to reinstate the photo interpretation course, is the interest being shown by state agencies, reiterating the need for this kind of educational service. As the agencies become acquainted with landsat and digital analysis products, their needs will probably grow. The university is not capable of this kind of instructional coverage now, but may be in the future.

University of Montana (Missoula)

The School of Forestry at the University of Montana has had a significant impact on remote-sensing education for many years. Following the acquisition of the 28,000-acre Lubrecht Experimental Forest, aerial photography was produced in 1938 to coincide with a ground-control survey of the area. Subsequently, a topographic map was produced using techniques employing this data in radial-line control extension and multiplex plotting. Charles W. Bloom, a forest surveying instructor, directed this work and incorporated the results of his work in his teaching.

Although no formal courses developed, airphoto interpretation instruction was included in courses in forest mensuration and management until 1953. That year, a course in Airphoto Interpretation was introduced by Professor Thomas Waldbridge. This course was continued until 1957 under the direction of James R. Wallis. In 1958, two new courses in Aerial Photographic Interpretation were introduced by Frederick L. Gerlach, who has directed this program in the School of Forestry since then. In 1965, curriculum changes added two courses under the titles

Air Photo Analysis and Advanced Airphoto Analysis. The latter course included an analysis of problems involved in the use of remote sensing media and the evaluation of remote sensing sources for resource information. In 1969, courses in Advanced Aerial Photogrammetry and Aerial Remote Sensing were introduced. The latter was the first university-level course to be offered under the title in the State of Montana.

Other departments of the University of Montana having interests in the remote sensing field over time include geology and geography. In 1958, the Department of Geology introduced a course in the Interpretation of Aerial Photos and Geologic Maps. The Department of Geography included aerial photo evaluation in a course in Map Interpretation, and geology dropped their course in 1970. Geography introduced Map and Airphoto Interpretation and geology offered Topics in Surface Processes and Remote Sensing in 1974.

The assistance of the Region One Offices of the U.S. Forest Service is significantly related to our program development. Particularly, the cooperation of the Geometric Services Unit (formerly the Aerial Photogrammetry and Mapping Section) of the Division of Engineering has been most beneficial to our instructional mission. This unit has been maintained as a complete and modern photogrammetric mapping facility since the early 1930's. The 1938 mapping of Lubrecht Experimental Forest was completed through the assistance of this unit. Most of the high-quality aerial photography and photographic reproductions used in our courses have been produced by this unit. Their laboratories and facilities have provided students with field-trip observation of photogrammetry and remote sensing in action. In advanced courses, photogrammetry and remote sensing students have gained laboratory experiences in an operational atmosphere.

A listing of courses offered at the University of Montana may be appropriate to a definition of present programs. The courses available at the present time include Map and Airphoto Interpretation (Geography 287), Aerial Photogrammetry (Forestry 351), Advanced Aerial Photogrammetry (Forestry 450), Aerial Remote Sensing (Forestry 451), Advanced Image Analysis (Forestry 454), Problems in Aerial Photogrammetry and Remote Sensing (Forestry 499), and Topics in Surface Processes and Remote Sensing (Geology 594). There are more courses available (Mathematics, Physics, Statistics, Computer Science, Cartography, etc.) designed for specialization in the remote sensing field.

The School of Forestry has supported a graduate program in photogrammetry and remote sensing at the master's degree level since 1950. The first master's thesis in the aerial inventory of forest stands was produced in 1953. Since then, nine masters theses have been produced in the remote sensing-related program in forestry. Two more are scheduled for completion this year. Several master's degrees with some remote sensing specialization have been completed in the Departments of Geology, Geography and Environmental Studies.

Although consideration has been given to the development of a degree program in remote sensing, the financial support required for such a program has not been available. Present realities include a forced retrenchment in faculty and a freezing of salaries due to a legislative student-faculty ratio requirement. Although the School of Forestry exceeded the requirement, three faculty positions were lost. Other limitations include financing for teaching equipment and teaching materials.

Students working toward the degrees of Bachelor of Science in forestry and Bachelor of Science in resource conservation probably have the greatest opportunity to develop a remote sensing specialty. With 45 or more free-elective credits, they can assemble a series of courses beginning with mathematics and physics that will provide them with a good natural resource oriented remote sensing specialization. Presently, we probably graduate about ten students a year who have ten or more credits directly in remote sensing.

The course Forestry 351 has continuously had the largest enrollment of any courses at the university in the field of remote sensing. This is a basic course in photogrammetry and remote sensing. For the past three years, it has enrolled over 100 students (125 this year). Most are forestry students, but the course does attract students from other departments. Enrollments in Forestry 450 and 451 have varied much over the years, averaging about six in 450 and 15 in 451. These enrollments are expected to increase.

Given the financing and the identity, we could develop an excellent specialization in aerial remote sensing. It would be a natural-resource-based program having a foundation in basic physical and natural sciences, a biological and technological framework, and an orientation toward integrated resource inventory. The elements of such a program presently exist at the University of Montana. The initiation of an undergraduate program in remote sensing would depend on the allocation of faculty time, funding for laboratory equipment and materials, and the support of the university and departmental administration.

In cooperation with the University Continuing Education Program, the School of Forestry sponsored a very successful short course on Aerial Photogrammetry: Mapping Natural Resources in March 1978. There were 45 applicants for the course having an enrollment limit of 25. The response to this course, during and after, was gratifying. The success demonstrates clearly the transformation of a latent demand in recent years into a real demand for remote sensing education at technical and professional levels in a regional context. Plans for repeat offerings of this course and other courses in the field are active.

The School of Forestry provides laboratory space for teaching photogrammetry and remote sensing at the basic and advanced levels. This space is nearly adequate for the present program, but it would not support expansion without more complete dedication of the space and improved equipment in the laboratories. Other departments have similar conditions. The Department of Geography hopes to occupy space for a cartography laboratory soon.

There is a significant shortage of equipment for teaching photogrammetry and remote sensing at the basic level. For example, lighting, light tables, quality stereoscopes, stereometers, precision scales, etc. are not available on an individual student basis.

For more advanced work, the School of Forestry has available a number of instruments including a Zeiss Stereotop, a Balplex ER-55 projection plotter, two Belfort (Kelsh type) projection plotters, stereoscopes, stereometers, and a well-equipped photographic darkroom. The Department of Geology has a Gaileo Stereomicrometer, a Bausch and Lomb Zoom Transfer Scope, a Zoom 240 Stereoscope, Richards Light Table and an optical projection image analyzer. The university computer center has a DEC-20 computer and a Calcomp plotter; the Forestry and Geology departments have computer terminals and mini-computers. These facilities and instruments are shared by advanced students.

The purpose of this report has been to present a situation in remote-sensing education that has been active for many years; one that has grown steadily over time; and one that has had a significant impact over time. (More than 1400 students have taken courses in photogrammetry, photo interpretation, or remote sensing since 1957.) Remote sensing education will continue to grow at the University of Montana. Considering the present restrictions on education funding, this growth will not be rapid nor will there be significant improvements in quality. Given additional funding for remote sensing education, our programs can achieve substantial improvements.

Discussion

There was general agreement in the group recognizing remote sensing as a tool within the traditional academic disciplines, in the present context, as opposed to structuring remote sensing education as a new discipline. It is probable that the institutions in this region can provide better educational service in this philosophical mode, which still allows for both undergraduate and graduate-level majors in remote sensing within departmental areas. This route for remote sensing education is being utilized at the University of North Dakota, the University of Montana, and South Dakota State University.

Both North Dakota and South Dakota have provided identity and demonstrated a commitment to remote sensing research by the establishment of institutes. Although of recent entry into the field of remote sensing, the University of North Dakota has made significant progress in identifying and coordinating the intra-dependent activities of remote sensing education, research, and service.

It seems clear that there is little opportunity for expanding the educational services within the region without the allocation of more resources to this endeavor. The limitation results from the intense competition for available resources within the university community. In relation to this, there may be some lack of acceptance of remote sensing within some institutions, which may be due to a lack of identity within these institutions. That this identity could be achieved by the establishment of departments of remote sensing and remote sensing curricula is paradoxical.

Discussion of the acceptance and identity problem reveals a lack of definition for the field of remote sensing. Since remote sensing methods are employed in so many disciplines, this condition may be natural. But it is still an apparent barrier to significant improvements in remote sensing education at the university level. The following definition of the field of remote sensing is offered for your critique.

> The integrated disciplinary design and use of airborne and spaceborne remote sensing systems for the acquisition of earth resource information. Wherein these systems, instruments are used to produce images or data, effectively extending human physiological capabilities through time, space, and the electromagnetic spectrum and involving all of the problems associated with spatially positioning and interpreting the image or data output of the systems.
>
> F.L. Gerlach, 1971

Summary

Most of the problems discussed relate specifically to the availability and use of teaching personnel, teaching equipment, laboratory space, and teaching materials. Administrative commitment and the allocation of resources to remote sensing education are the apparent solutions. These solutions may be obtainable through more and better public visibility and political efforts on behalf of remote sensing education.

The Northeastern States Academic Group believes that this conference (CORSE-78) has been a significant step toward the improvement of remote sensing education. We have had the opportunity to know each other better, to discuss our mutual problems, and to share our experiences in this exciting field. Better cooperation, sharing of highs and lows, and improved remote sensing education can be expected.

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SUMMARY OF PREPARED TALK

FOR

DATA ACQUISITION WORKSHOP

Presented at

CORSE 78
Palo Alto, California

John E. Estes, University of California, Santa Barbara
John Miller, University of Alaska
Phil Slater, University of Arizona

The goal of this workshop discussion was to provide participants with some thought of the panel on the teaching of the acquisition of ground aerial and satellite data in remote sensing. The session was chaired by Dr. Estes and the speakers discussed in turn: John Miller, Field Data for Teaching from the Viewpoint of the Earth Sciences; John Estes, A Teaching Strategy for a Lecture on the Acquisition of Aerial and Satellite Remote Sensor Data; and, Phil Slater, Future Sensor Systems.

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A Teaching Strategy for a Lecture on The Acquisition of Aerial and Satellite Remote Sensor Data

By John E. Estes

John Miller has given you some insights on the collection of "ground truth/field verification data." I would now like to turn my attention to the acquisition of aircraft and spacecraft data. Again, this will be followed by Phil Slater who will discuss with you the need to keep up with information concerning data from future satellite systems.

In my class, when I discuss the acquisition of remotely sensed data from aircraft platforms, I typically discuss it with reference to three options open to individuals wishing to acquire such data. These options are, that an individual may:

- buy existing coverage
- contract for new coverage or
- fly his or her own coverage.

The choice of which course to follow is basically dependent upon what the individual's interpretation objectives are and what cost constraints he or she is operating under.

Buying Existing Coverage

Many people in remote sensing today are aware of the United States Department of the Interior's EROS Data Center in Sioux Falls, South Dakota. At Sioux Falls, the U.S. Department of Interior Geological Survey has established a center where holdings of the department can be assessed. By writing EROS, individuals can obtain a listing on all the holdings for a particular given longitude and latitude location which have been collected by the National Aeronautics and Space Administration and most elements of the Department of Interior. In addition, through cooperative agreements with other governmental agencies such as the Corp of Engineers, holdings of these agencies can be addressed as well. An inquiry to EROS should specify: the longitude/latitude boundaries of the area desired; the type of imagery analog, digital, black and white, color positive or negative, print or transparancy required; and the amount of cloud cover you will "live with."

In addition to the EROS Data Center, another U.S. Department of the Interior Office where individuals can write to get a current listing of the status of aerial photographic coverage of the U.S. is:

National Cartographic Information Center
U. S. Department of the Interior
Geological Survey
Reston, Virginia 22092

Upon request this map information office will supply free in map form, a publication on the status of aerial photography in the U.S. The map an individual request will receive will show all areas in the United States, by county, that have been photographed by or for the Agricultural Stabilization and Conservation Service, the Forest Service, the Soil Conservation Service, the Corp of Engineers, the Air Force, the National Ocean Survey, the Geological Survey, and commercial firms. Names and addresses of agencies holding the negatives for the photographs are printed on the back of the map and inquiries should be sent directly to the appropriate organizations. At the present time there is no centralized laboratory or facility which can furnish prints of all government photography to any given individual or institution.

Most aerial photography purchased through federal agencies such as this are taken on panchromatic film at a scale of between 1:12,000 and 1:14,000. The dates of the photographic coverage usually varies from about 2-8 years although agricultural regions, reservoirs, and urban areas are being photographed at more frequent intervals. Photo index sheets of existing photography can be viewed at local regional offices of the Agricultural Stabilization and Conservation Service, Forest Service or the Geological Survey.[1]

It should be mentioned before leaving this topic that possibly the largest portion of recent U.S. air photo coverage is held by agencies within the United States Department of Agriculture. There are some nearly 500 million acres of crop lands in the United States, In 1936 the United States Department of Agriculture began an aerial photographic program with the sole purpose of monitoring croplands, particularly those crops involved in price support programs. Some 350 million of these 500 million acres are considered significantly active and they are flown about once every 5-10 years. Therefore, in areas of cropland throughout the United States, historical records may date back to 1936 with a maximum interval of about 10 years. Information concerning this type of coverage can be obtained from:

Western Laboratory
Aerial Photographic Division
Agricultural Stabilization and Conservation Service
United States Department of Agriculture
2511 Parleys Way
Salt Lake City, Utah 84109

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[1] Avery, T.E., 1977. Interpretation of Aerial Photographs, 3rd edition, Burgess Publishing, Minn., Minn. 392p.

There are many uses for purchased photography. These uses include land use mapping, topographic mapping, use for photo mosaics, use in agricultural investigations, water demand studies, snow field mapping, etc.

With respect to satellite data, the largest and most complete record of holdings is kept by the EROS Data Center at Sioux Falls. Individuals wishing to obtain prints or high density digital tapes of Landsat coverage should write:

EROS Data Center
U.S. Geological Survey
10th & Dakota
Sioux Falls, South Dakota 57198

If the reader desires to obtain data from any of the meteorological satellites he should write to the National Oceanographic and Atmospheric Administration:

NOAA/NESS
World Weather Building
Washington, D.C. 20233

Ordering and purchasing information can be provided there.

There are a number of both advantages and disadvantages to using existing coverage. The one advantage is that acquisition of this type of imagery may be economical - as little as $2.00 per print. It is often convenient to just order what you need; you can order enlargements and sequential imagery when available. However, there are also disadvantages to the acquision of existing coverage. These include the fact that you have no control over the photo specifications - that is what types of cameras were used, what film, filters, altitude, season of the year, etc. You also have no control over photo quality. You essentially take what is already available; although in many cases this may be excellent.

Contracting For New Photography

In contracting for new photography, it is often appropriate to contact an aerial survey or photogrammetric engineering firm. There are several ways of doing this - you can either look in the yellow pages of your local phone directory under "Photogrammetric Engineers" or "Aerial Surveys." Or, you may look for an advertisement in a professional publication such as Photogrammetric Engineering and Remote Sensing.

In contracting for new coverage, the reader should be aware of the need for a good background in the preparation of specifications for flying aerial photography. Not only in the technical aspects such as what films, filters, scales, season, time of day, overlap and sidelap, etc. that he would like; but, also the technical aspects of contracting and bidding as well.

Then there is the subject of costs. Costs are very difficult to generalize and depend upon the size and shape of the area to be photographed. In addition cost are dependent upon the weather conditions at the time of year in which the photography is to be acquired, and the photo specifications. Generally speaking, if areas are irregular in shape and large in size, they are more costly. If your mission must be flown at a given time of year when weather conditions may prove difficult, it may be even more costly. And if you have some very complex photo specifications, it will also be more costly. In the local Santa Barbara area where I teach my class, mobilization costs for an aerial photographic firm typically run on the order of $175. This is just the cost of initially getting the aircraft off the ground. For conventional coverage (1:20,000 panchromatic minus blue, 9" X 9"), the costs will run on the order of $10 per exposure.

The costs for color aerial photography will run on the order of $12-$15 per exposure. Again, there are advantages and disadvantages to contracting for new photography. The advantages are that you have direct control of the photo specifications and that you control the photo quality. Disadvantages include the fact that this can be relatively expensive and involves the legal aspects of contract negotiations.

Flying Your Own Aerial Photography

This section should be prefaced by a warning: "Let the Professionals do a Professional Job." Examples of professional jobs are photos to be taken for precise photogrammetric work - aerial photographic coverage taken of very large areas and photos which need to be flown to rigid specifications. Examples of where non-professional aerial photo missions might be appropriate include those smaller areas where a limited amount of coverage is needed - photos for general interpretation work, and photos for public relations work. In addition, a good example of the type of photography which lends itself to the do-it-yourself method is aerial photography taken from light aircraft for ground truth or field verification purposes. There are many ways of acquiring the equipment and materials to take your own photography. You can either rent or purchase an aircraft or helicopter. You can rent or purchase cameras; 35mm, 4X5, speed graphics, or 9X9 aerial. You can also purchase your own films and filters. Here again, you must be aware of all the factors which come into the planning of photo missions. Decisions must be made as to the optimum specifications for the particular job in mind such as; what films, filters, scales, time of year, time of day, etc. are best to accomplish the task which you have set out for yourself.

Again, costs here are very difficult to generalize but in a table listing the two extremes which I have used in classes may interest you. It should be noted costs here are approximate and subject to constant change and only included to give the student a general perspective.

EXAMPLE OF TWO EXTREMES

	ECONOMY	DELUXE
Airplane	- rental @25 to $50/hr. with/without pilot purchase 2nd hand plane for $2,000.	Purchase new Cessna citation (like a Lear) with electronic navigation aids @ $750,000.
Camera	- K-20 NEW $179.50 USED $ 75.00	Ziess 6", f.l. precision camera 9"x9" format @ $35,000.
Films	- Outdated Panchromatic (by 18-20 months) @ $2./50 exposure roll.	Ekta Aero IR @ $350 for 50 exposure roll.

All the advantages and disadvantages of flying your own coverage (aerial photography) are similar to having it flown. The advantages include direct control over photo specifications, and to some extent photo quality. Flying your own photography can be very convenient and economical. The disadvantages include the fact that it can often be an uneconomical venture and can also be quite dangerous.

For more information concerning the purchasing and use of aerial photography, the reader is directed to Avery, 1977, Chapter 5 on flight planning, pages 81-100. For additional information the reader is also directed to the book by Floyd S. Sabins, Jr. Remote Sensing Principles and Interpretation, 1978, W.H. Freeman, Co., Chapter 2, pg. 48 has sources of aerial photographs, Chapter 3 on man-satellite imagery has sources of photographs on page 62 and Chapter 4 on Landsat imagery has sources of Landsat data on page 77. Both of these works are excellent and should be required reading for any individual seeking to teach a class on the acquisition of remotely sensed data.

FIELD DATA FOR TEACHING FROM THE VIEWPOINT OF THE EARTH SCIENCES

John M. Miller
Geophysical Institute
University of Alaska

The acquisition of field data for educational uses in the earth sciences is somewhat limited at the University of Alaska owing to seasonal constraints. The school year begins in September and ends in May; winter runs from October to April so that obtaining data from field trips is too weather dependent to achieve an ideal mix of class or laboratory exercises with field observations. However, we can transform an apparent hindrance into a major strength by emphasizing the synoptic advantages of small-scale remote-sensing data plus the benefits of multistage sets of data.

The use of remote sensing in teaching the earth sciences is fundamental, and many of the new texts for introductory geology introduce the use of Landsat imagery. Remote sensing makes more sense in teaching geology in Alaska than elsewhere owing to a lack of other types of data and the inaccessability of a large portion of the state. There are five main areas which are heavily dependent upon remotely sensed data: lineament analysis correlated with locations of mineral and energy resources; use of spectral signatures to discriminate types of exposed rocks and alteration zones; spectral signatures of stressed vegetation related to mineralization of the soil; landform studies; and active surficial processes. We have done relatively little with geologic applications of digitally processed Landsat data owing to a lack of facilities and the difficulty of integrating these complex techniques into undergraduate curricula.

In some respects the geologic application of remote-sensing data is like putting together a jigsaw puzzle. There is far more satisfaction from completing the final product than from studying a small group of pieces. It is important to learn the detailed skills of field analysis of rock types, such as horizontal or tilted bedding planes, thickness, uniformity, color, joints, grain size, shape and pattern, and open or closed pore spaces. The study of rock outcrops is important, but it is like one piece of the overall puzzle and can become secondary to the interpretation of remote-sensing data. From a philosophical point of view, we would be better advised to refer to 'field verification' rather than 'ground truth', for 'truth' must take into account evidences from many observations, some of which may be ambiguous at best or contradictory at worst. While we retain the subjective notion that viewing objects up close produces finer, better and more accurate descriptive data, this is mostly true with discrete objects of small dimensions, and is less reliable with analyses of regional scope.

So we teach students how to map geologic features from multistage sets of data starting with the smaller-scale forms of data such as Landsat and radar and moving into high and low-altitude aerial photography. The geology majors can later do the field work during a special summer course which can verify the results from previously analyzed remote-sensing data. The field work presents opportunities for discovery and learning which reinforces the previous analysis and interpretation of images. Many questions can be addressed, such as how thin or sparse vegetation influences the spectral discrimination of exposed rocks; why lineaments are so difficult to observe on the ground and which ones should be called faults; whether details of the 1st order dendritic patterns add useful information to the overall interpretation; and the importance of ground verification for the interpretation of some geomorphic features (eskers, drumlins, kettles) and less need for others (glacial scouring, lateral and terminal moraines and old beach lines).

The greatest need for our teaching program is for data from a broad spectrum of sensors from various locations in Alaska which have been acquired within a narrow frame of time so that students can compare the types of data to recognize the strengths and weaknesses of each media and to better understand the best applications for each. We do not need more of what we presently have--some aerial photography here, radar imagery from there, and thermal IR from elsewhere. We need data packages from sites selected for geologic applications plus those from other regions dominated by urban, agriculture, and wildland vegetation. The earth-science majors should not restrict their study to purely geologic regions of interest. They need also to learn how vegetation and land-use patterns influence geologic interpretations of remote-sensing data.

As a final note of interest, we have found that it is important not to overlook the use of low sun-angle Landsat images in the northern latitudes. These winter scenes tend to suppress the influence of vegetation caused by snow cover and defoliation of deciduous species. The low level of illumination also enhances the more subtle geomorphic features that cannot be recognized at other times of the year. NASA's practice is to acquire Landsat MSS data only when the sun angle is above ten degrees. We have found that images with sun angles from ten to twenty degrees are ideal for geologic interpretation when coupled with summer images of the same area. And, upon special request, NASA will acquire MSS data in the high-gain mode down to sun angles of two or three degrees.

THE POINTABLE MULTISPECTRAL LINEAR ARRAY SYSTEM AND THE LARGE FORMAT CAMERA FOR EARLY 1980 SHUTTLE PAYLOADS

Philip N. Slater
Chairman, Committee on Remote Sensing
Professor, Optical Sciences
University of Arizona

Future Sensor Systems

Dr. Jack Estes has just described the requirements we must specify in order that we can obtain the type of remote sensing data we need from aircraft platforms. He also described the procedures for obtaining remote sensing data from the EROS Data Center that have been collected as part of the present Landsat program. With the help of several viewgraphs, I shall describe two future systems under consideration by NASA to provide us with data and facilities beyond those obtainable by Landsat 1, 2, 3 and D (the Thematic Mapper). It is worthwhile for all of us to be aware of these future systems for two reasons. First, because our inputs to NASA at this stage may aid in the design decisions now being made and thus to the quality of space remote sensing data we will have at our disposal in the 1980s. Second, because of our important role as educators of the next generation of remote sensing specialists, we should be describing the next generation sensor systems in the classroom today.

The first of these new systems has had several different names: the High Resolution Pointable Imager (HRPI), the Multispectral Linear Array (MLA) and, very recently, the Multispectral Resource Sampler (MRS). The design is not frozen at this point. The reader will appreciate that the performance can be modified considerably hence the number of possibilities described by the various options. As you will see, it has several important features:

1) By virtue of its crosstrack pointing capability, it can provide coverage of limited selected ground areas on a 2 or 3 day frequency
2) Fore and aft pointing will allow studies of atmospheric effects and multidirectional reflectance effects to be made.
3) Its higher spatial resolution from space will provide a multistage capability. This should prove of considerable value in urban studies, in overseas agricultural studies where fields are too small for analysis using current Landsat data and in determining to what extent ground truth and aircraft overflight requirements may be relaxed by including a high resolution capability in future space systems.

The second system I shall describe is the Large Format Camera (LFC) to be flown on space shuttle missions. This photographic system will provide us with high quality color stereoscopic coverage of the earth's surface. The purpose of course is to enable global topographic maps to be compiled and for this reason the imagery will be compatible with conventional stereo plotting equipment that is routinely used worldwide.

Should you have important comments or suggestions regarding these new sensors, contact Dr. C. C. Schnetzler at NASA/Goddard Space Flight Center regarding the MRS, and B. H. Mollberg at Johnson Space Center or Dr. F. J. Doyle at the U.S. Geological Survey, Reston, regarding the LFC.

The Pointable Multispectral Linear Array System

We are all familiar with the first three Landsat sensor payloads, the last of which was placed in orbit successfully in March of this year. We are also fairly familiar with the Thematic Mapper (TM) system which, with the old reliable Multispectral Scanner (MSS), comprises the sensor payload for Landsat D to be launched in 1981. The TM over the past couple of years of system definition has enjoyed some notoriety as the USGS and others have criticized its objectives, which are largely agricultural; its incompatibility, in terms of image cataloging with the earlier Landsat systems; and its much higher telemetry data rate which is incompatible with existing ground receiving stations.

These problems have not delayed the development of the TM, two of which are presently being fabricated, the second for launch in 1984 on what is currently referred to as Landsat D', the backup to Landsat D. (If Landsat D is successful and becomes Landsat 4, then Landsat D' will be renamed Landsat E.) What is generally not well known is that the TM is a very expensive system to fabricate and that the initial estimate of cost to completion has risen almost 50% since project initiation less than a year ago.

For the above reasons it is unlikely that follow-on TM systems will be built. Furthermore, the relatively new linear array CCD technology has the potential of providing comparable system performance at a much reduced cost. NASA is considering several different system options for a pointable multispectral linear array (MLA) system to replace the MSS on Landsat D', and to be orbited with the second TM in place of the MSS. This first system is being considered as a research rather than a quasi-operational system. However, it is anticipated that an MLA-type system could be an operational earth resources system in the late 1980s. The MLA has the potential of making some important measurements, impossible with the MSS and TM, by virtue of its pointing capability. These are indicated on the following pages which come from a NASA/GSFC presentation on the MLA.

MULTISPECTRAL LINEAR ARRAYS (MLA) SENSOR FOR LANDSAT D'

OBJECTIVE

I. To provide unique opportunities for Earth Survey Applications Experiments beyond those possible with Thematic Mapper.

- New Instrument Capabilities
  - -- More frequent temporal coverage
  - -- Higher spatial resolution
  - -- Narrower spectral bands
  - -- Higher radiometric sensitivity
  - -- Greater precision in mapping geometry
- Research in interpretive techniques
  - -- Anisotropic reflectance studies
  - -- Atmospheric correction studies
  - -- Stereographic imaging

II. To provide an engineering demonstration of MLA sensor technology

-- Validate performance, physical characteristics and costs

III. Design to be modular

-- For easy modification after retrieval and refurbishment

-- To simplify reconfiguration from mission to mission

IV. Provide an easy transition to follow-on operational or research sensors

MULTISPECTRAL LINEAR ARRAY (MLA) SENSOR FOR LANDSAT D'

MLA SENSOR TECHNOLOGY APPLICABLE TO WIDE RANGE OF FUTURE RESOURCES MISSIONS
  CROP CLASSIFICATION, WATER MANAGEMENT, GEOLOGY, AGRICULTURE MANAGEMENT, ETC.

FLIGHT OF MLA SENSOR ON LANDSAT D' WILL

- VALIDATE CAPABILITIES
  - OF SYSTEM TO ACQUIRE THE NEEDED INFORMATION
  - OF SENSOR TO PROVIDE DATA OF REQUIRED QUALITY
- DEVELOP USER DEMAND FOR THESE NEW CAPABILITIES
- PROVIDE EASY TRANSITION TO FOLLOW ON MLA SENSORS AND SYSTEMS

REQUIRES FY 80 NEW START FOR SENSOR AND ASSOCIATE RESEARCH PROGRAM

MULTISPECTRAL LINEAR ARRAYS (MLA) - OPTIONS

OPTIONS WERE DERIVED USING THE FOLLOWING GROUND RULES:

SENSING ATTRIBUTES NEEDING IMPROVEMENTS - IN PRIORITY ORDER

1. OBSERVATION FREQUENCY - TEMPORAL COVERAGE
   DEMONSTRATE BY USE OF CROSS TRACK OFFSET POINTING WITH OPTIMIZED ORBIT
2. SPATIAL RESOLUTION
3. SPECTRAL RESOLUTION
4. RADIOMETRIC RESOLUTION

ALL CAN BE ACHIEVED AT MODEST COST USING MLA SENSORS

SYSTEM SHOULD VALIDATE OBSERVATION REQUIREMENTS FOR FUTURE LANDSAT'S

POSSIBLE SEQUENCE

LANDSAT E - HIGH RESOLUTION POINTABLE IMAGER

LANDSAT F - WIDE FIELD SENSING FOR BETTER TEMPORAL RESOLUTION

THE THEMATIC MAPPER WILL FLY ON LANDSAT D'. MSS MAY BE REPLACED BY MLA SENSOR.
MLA SENSOR MUST BE COMPATIBLE WITH LANDSAT D DATA RATES
DESIRABLE TO LIMIT MLA DATA TO 15 MB/S TO MINIMIZE CONFLICTS WITH TM

OPTIONS MUST COVER RANGE OF FEASIBLE IMPROVEMENTS

HAVE REAL DIFFERENCES IN COST AND CAPABILITIES

SUMMARY OF OPTIONS

I. FINE RESOLUTION POINTABLE IMAGER (FRPI)

-- A 10M RESOLUTION, NARROW FIELD-OF-VIEW SENSOR WITH A 2-AXIS STEERABLE MIRROR

II. DUAL RESOLUTION POINTABLE IMAGER (DRPI)

-- A 15M/30M GROUND RESOLUTION, NARROW FIELD-OF-VIEW SENSOR WITH A 2-AXIS STEERABLE MIRROR. MULTIPLE MODES PROVIDED.

III. SELECTABLE SPECTRAL RESOLUTION POINTING IMAGER (SSRPI)

-- A 30M RESOLUTION, NARROW FIELD-OF-VIEW SENSOR WITH 5 SPECTRAL BANDS EACH OF WHICH IS SELECTABLE IN FLIGHT THROUGH AN INDEXING FILTER, 2-AXIS STEERABLE MIRROR.

IV. ELECTRONICALLY POINTABLE MULTI-TEMPORAL SAMPLER (EPS)

-- A 30M RESOLUTION, WIDE FIELD-OF-VIEW SENSOR WITH STEERING IN THE ACROSS TRACK DIRECTION ACCOMPLISHED ELECTRONICALLY BY SEGMENT SELECTION.

V. MIXED RESOLUTION IMAGER (MRI)

-- A 40M/80M RESOLUTION WIDE FIELD-OF-VIEW SENSOR. NOT POINTABLE.

SENSOR OPTION I - FRPI

FINE RESOLUTION POINTABLE IMAGER

KEY FEATURES

Ground Resolution:	10m
Swath Width:	40km
No. Spectral Bands:	4; $\Delta\lambda = 0.05\ \mu m$; NE$\Delta\rho = 0.49\%$
Pointing:	2 axis; ± 45°; mirror
Data Rate:	85 Mbps
Optics Size:	40 cm diameter x 140 cm focal length

USES

More frequent temporal sampling ($\leq$ 5 days)

Anisotropic reflectance studies

Very high resolution mapping for

flood damage assessment, urban land use/change, field boundaries

Stereo imaging

Atmospheric correction studies

RISKS

High cost Does not fit Landsat MSS size, weight, power, or data rate

SENSOR OPTION II - DRPI
DUAL RESOLUTION MULTI-MODE POINTABLE IMAGER

KEY FEATURES

Ground Resolution: 4 Bands @ 30m plus 2 bands @ 15m

No. of spectral bands: 6; $NE\Delta\rho = 0.5\%$

Pointing: 2 axis; ± 45°; mirror

Swath Width: 30km

Data Rate: 15Mbps

Note: At this data rate there are the following modes:

Mode A: 4 bands at 30m/30km swath plus 1 band at 15m/30km
Mode B: 2 bands at 15m/30km swath
Mode C: 4 bands at 30m/30km swath plus 2 bands at 15m/15km

Optics Size: 15 cm diameter x 70 cm focal length

USES

- Frequent temporal sampling (≤ 5 days)
- Anisotropic reflectance studies
- High resolution mapping (1:24000)
- Stereo imaging
- Atmospheric correction studies

RISKS

- Moderate cost
- 2 axis pointing mirror

NOTE: It may be possible to have some in-flight selection of spectral bands if spectral resolution or inherent registration capabilities are relaxed.

SENSOR OPTION III - SSRPI

SELECTABLE SPECTRAL RESOLUTION POINTING IMAGER

KEY FEATURES

Ground Resolution:	30m
Swath Width:	30km
No. Spectral Bands:	5 each with selectable bandpass; can be as narrow as 20 nm; $NE\Delta\rho = 0.4\%$
Pointing:	2 axis; ± 45°; mirror
Data Rate:	15 Mbps
Optics Size:	15 cm diameter x 35 cm focal length

USES

Multi-temporal sampling (≤ 5 days)

Anisotropic reflectance phenomena

Stereo imaging

High resolution spectral analysis

Atmospheric correction studies

RISKS

Low to moderate cost, Indexing filters, Pointing mirror

SENSOR OPTION IV - EPS
ELECTRONICALLY POINTABLE MULTI-TEMPORAL SAMPLER

KEY FEATURES

Ground Resolution: 30m

Swath Width: 185km (narrow segments are electronically selected from within this swath up to total of 60km)

Pointing: 1 axis; electronic; within swath width

Data Rate: 15 Mbps

No. Spectral Bands: 4; identical to TM; $NE\Delta\rho = 0.1\%$

Optics Size: 15 cm diameter x 35 cm focal length

Note: It is proposed that two sensors be used and aligned either side of TM's FOV for a total swath of 555 km. This permits selected targets to pass within FOV at more frequent intervals (< 9 days) using one spacecraft.

USES

More frequent temporal sampling

Can follow geologic features because of inertialess pointing

RISKS

High-to-moderate cost

Wide field optics

SENSOR OPTION V - MRI

MIXED RESOLUTION IMAGER

KEY FEATURES

Ground Resolution:	2 bands @ 80m; 1 band @ 40m
Swath Width:	185 km
No. Spectral Bands:	3; $NE\Delta\rho = 0.1\%$
Data Rate:	15 Mbps
Pointing:	None
Optics Size:	8 cm diameter x 26 cm focal length

USES

Semi-operational continuation of Landsat 1, 2, and 3 type data

Develop a prototype of a possible operational sensor

RISKS

Low cost

Wide Field optics

ENGINEERING CHARACTERISTICS OF POTENTIAL MLA SENSORS FOR LANDSAT D'

MLA Options	Resolution IFOV, M	Bands, No.	Swath Width, KM	Pointing Capability	Data Rate Mbps	Comments
FRPI	10	4	40	2 axis, ±45°	85	Highest cost. Heavy, etc.
DRPI						
Mode A	30 - 15	4 - 1	30	2 axis, ±45°	15	Mixed resolution system helps preserve resolution at large offset pointing angles. Moderate cost.
Mode B	15	2	30	2 axis, ±45°	15	
Mode C	30 - 15	4 - 2	30 - 15	2 axis, ±45°	15	
SSRPI	30	5	30	2 axis, ±45°	15	In orbit filter change for spectral band selection. Moderate cost.
EPS	30	4	60	Electronic selection	15	Electronic selection of 60km FOV from 185 km FOV. High cost. Wide field optics.
MRI	80 - 40	2 - 1	185	None	15	"Operational precursor." Modest cost. Wide field optics

NOTES: FRPI may be incompatible with MSS space availability on Landsat D'.

All spectral bands ≤ 20 nm for 30m channels; ≤ 80 nm for 15m channels; ≤ 80 nm for 10m channels in FRPI.

Calculated for λ_0 = 700 nm, 45° SZA, R=20%, NEΔR=0.5%, exceeds TM performance.

All bands to be between 400 nm and 1000 nm - silicon detectors.

SOME POTENTIAL APPLICATIONS OF VARIOUS MLA OPTIONS

	FRPI	DRPI	SSRPI	EPS	MRI
BASED ON OFFSET POINTING CAPABILITY				“OPERATIONAL” DEMO. OF CROP EST.	NO EXPERIMENTAL ADVANTAGES FOR THIS SYSTEM “OPERATIONAL” PRECURSOR
STEREO COVERAGE (FOR TROPOSPHERIC MAPPING)	V	V	V -		
ANISOTROPIC REFLECTANCE STUDIES (PRIMARILY AGRICULTURE)	V	V	V		
ATMOSPHERIC CORRECTION STUDIES	V	V	V +		
LINEAMENT DETERMINATION	V	V	V		
BASED PRIMARILY ON IMPROVEMENTS IN TEMPORAL RESOLUTION					
RANGE MONITORING	V	V M	V	V -	
SNOW MAPPING	V	V	V	V -	
CROP PHENOLOGICAL DISCRIMINATION	V	V M	V +	V -	
CROP STRESS DETECTION	V	V M	V +	V-	
WEED INFESTATION DETECTION	V	V M	V	V -	
IRRIGATION SCHEDULING	V	V M	V	V -	
FOREST INSECT AND DISEASE DAMAGE DETECTION	V	V M	V +		
WATER QUALITY MONITORING	V	V	V +-	V -	
GEOBOTANICAL MINERAL EXPLORATION	V	V	V +-		
SHORT LIVED EVENT MONITORING (FLOOD, LANDSLIDE, ETC.)	V	V	V -	V -	
BASED PRIMARILY ON IMPROVEMENTS IN SPATIAL RESOLUTION					
SMALL FIELD CROP CLASSIFICATION	V	V M	-		
FLOOD PLAIN MAPPING	V	V	-		
FOREST SPECIES MAPPING	V	V M			
LAND USE MAPPING	V	V M	-		
ROCK UNIT MAPPING	V	V	-		
MINERALIZED (ALTERATION) ZONE MAPPING	V	V	+-		
BATHYMETRY	V	V	+-		

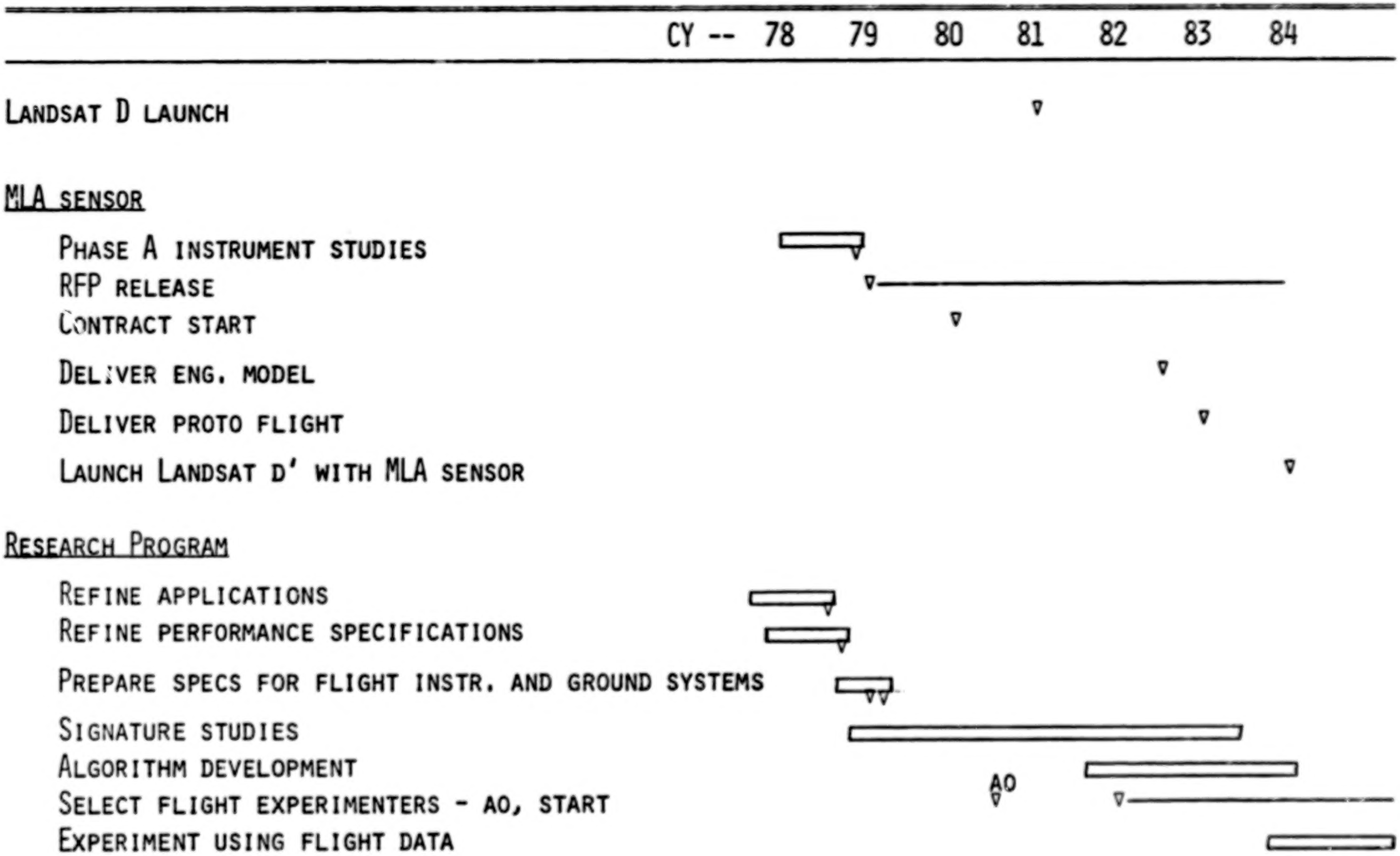
KEY

V POTENTIAL APPLICATIONS WITH THIS SENSOR
M MIXED RESOLUTION HELPFUL WITH MULTISTAGE SAMPLING OF LARGE AREAS
+ APPLICATIONS THAT MAY BENEFIT FROM HIGH SPECTRAL RESOLUTION
- APPLICATIONS THAT WILL BE AFFECTED BY LACK OF 15M SPATIAL RESOLUTION IN THE SSRPI
- APPLICATIONS THAT WILL BE AFFECTED BY THE LIMITED OFFSET POINTING CAPABILITY OF THE EPS

ASSOCIATED RESEARCH PROGRAM IN SUPPORT OF MLA SENSOR FOR LANDSAT D'

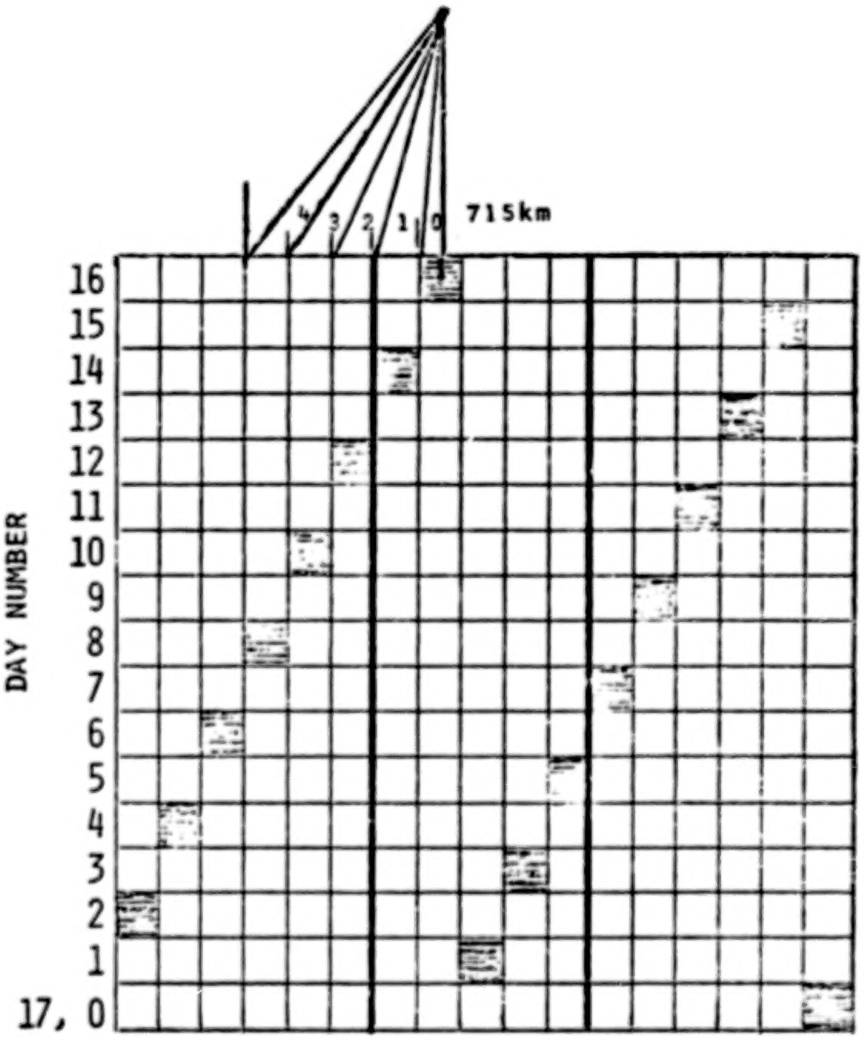
- CONSIDER THE PROJECTED MLA SENSOR CAPABILITIES, FUTURE SENSING NEEDS AND BENEFITS
    - ASSESS AND PRIORITIZE POTENTIAL APPLICATIONS TO BE STUDIED
    - FORM WORKING GROUPS AROUND SELECTED APPLICATIONS
        - DEFINE THE SENSOR PERFORMANCE REQUIRED
        - ACQUIRE SIGNATURE STUDIES IN SUPPORT OF SELECTED APPLICATIONS; LABORATORY, FIELD, A/C
        - DEVELOP ALGORITHMS TO ACQUIRE PARAMETERS FROM THE DATA
        - DEVELOP A SCHEDULING STRATEGY FOR THE SENSOR
        - DEVELOP USERS FOR THE EXPERIMENTAL DATA
        - CONDUCT EXPERIMENTS WITH THE FLIGHT DATA
        - PUBLISH RESULTS

SCHEDULE - MLA SENSOR FOR LANDSAT D'



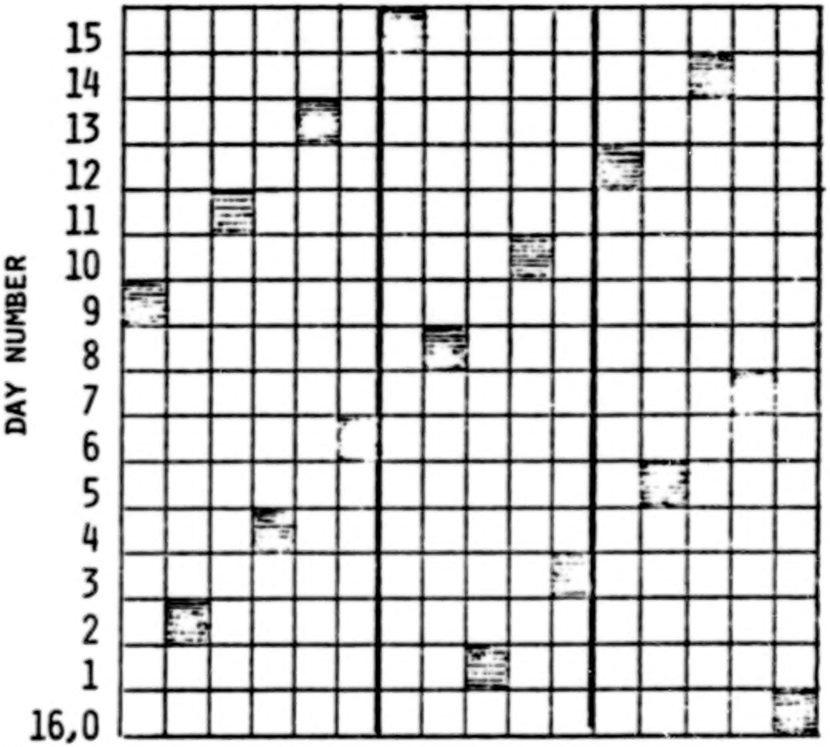
SWATH'S OFFSET	Φ_I	DIST. KM	ZENTIH ANGLE	RESOLUTION LOSS X	RESOLUTION LOSS Y
1/2	0	80	7°	0%	1%
1 1/2	1	241	21°	5%	12%
2 1/2	2	402	32°	16%	37%
3 1/2	3	563	45°	29%	74%
4 1/2	4	724	50°	46%	126%

H	715KM
I	98.25°
REPEAT PERIOD	17 DAYS
ORBITS/CYCLE	247
ORBIT TRACE SPACING	161KM
TM SCAN WIDTH	187KM
SCAN ANGLE	14.9°
OVERLAP	16 PERCENT
RESOLUTION	30.4 METERS


715km
4
3
2
1
0
DAY NUMBER
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
17, 0

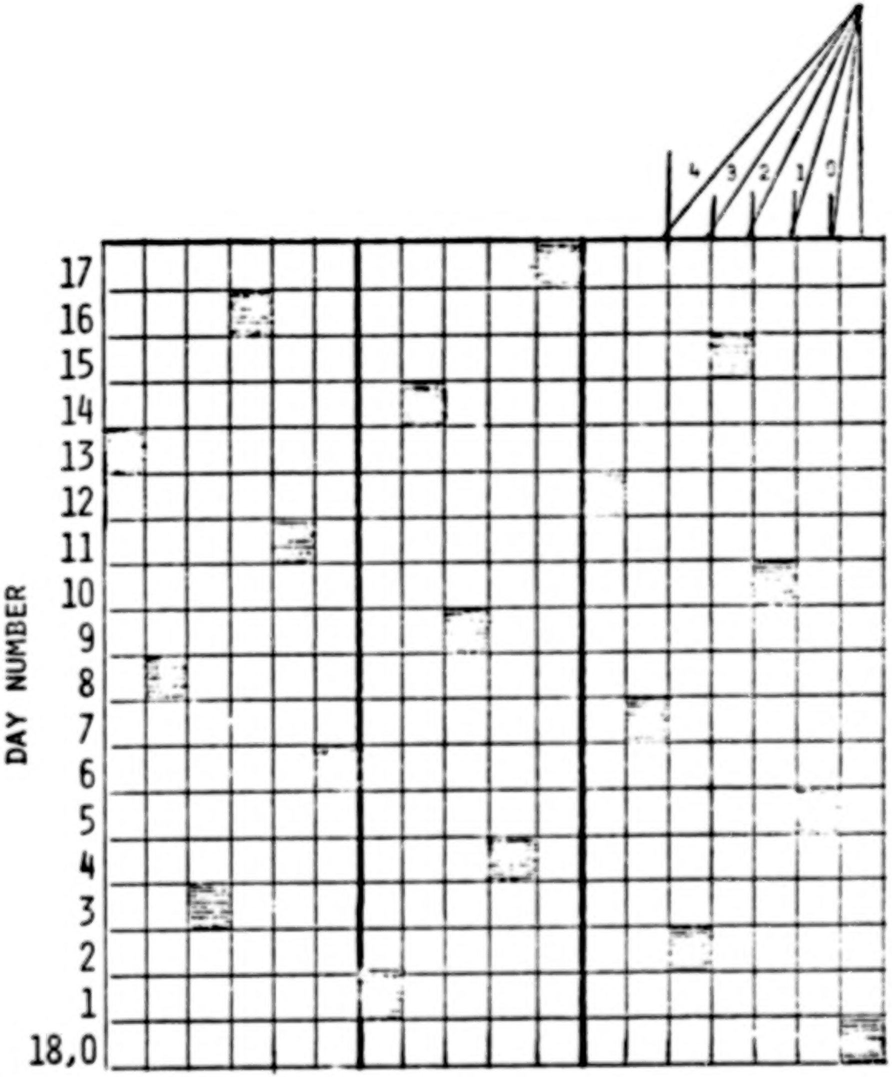
2-2-9-2-2 REPEAT FREQUENCY

H	705KM
I	98.2°
REPEAT PERIOD	16 DAYS
ORBITS/CYCLE	233
TRACE SPACING	170
SCAN WIDTH	185
SCAN ANGLE	14.9°
OVERLAP	10 %
RESOLUTION	30 M



2-5-2-5-2 REPEAT FREQUENCY

H	761KM (NOTE 689KM SIMILAR)
I	98.44
REPEAT PERIOD	18 DAYS
ORBITS/CYCLE	259
TRACE SPACING	153KM
SCAN WIDTH	199KM
SCAN ANGLE	14.9°
OVERLAP	30%
RESOLUTION	32.4M


4
3
2
1
0
DAY NUMBER
17
16
15
14
13
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4
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2
1
18,0

3-5-5-3-2 REPEAT FREQUENCY

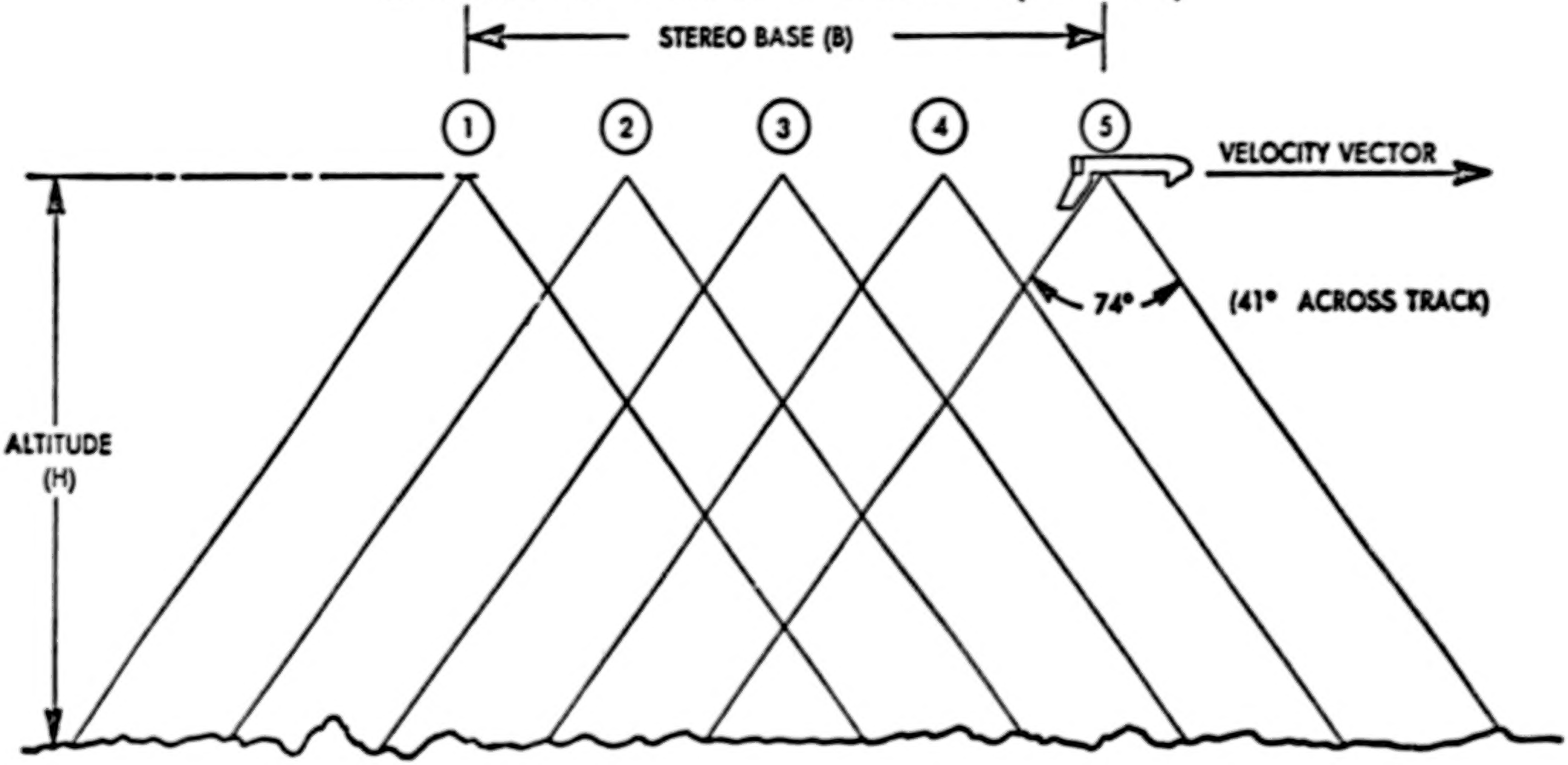
The Large Format Camera

The Large Format Camera (LFC) is scheduled for an early Shuttle launch in 1981. The system will provide a continuation to the early hand-held earth photography conducted on the Mercury, Gemini and Apollo programs which culminated with the well-known S-064 multispectral camera experiment on Apollo IX and the more sophisticated SI90a multispectral and SI90b high resolution cameras which were hard-mounted systems used in the Skylab missions. The following pages describe the LFC system and come from a NASA/JSC presentation on the system.

The important attribute of the system is that it can obtain high (≈10 m) spatial ground resolution, a relative position accuracy of ±14 m and a relative heightening accuracy, by virtue of stereographic coverage of between 7 and 28 m, depending on the base-to-height ratio used. A potential problem of the system is that it will orbit *in* the Shuttle. Past experience has been that man-attended photography experiments have not been as successful as automated image collection systems. For example, the MSS on the Landsat program has been more successful than the SI90a and SI90b experiments on Skylab. With a change in priority, perhaps this problem can be solved on the Shuttle.

PARAMETER			SPECIFICATION	
LENS:	Focal Length		30.5 cm	(12 inches)
	Aperture		f/6.0	(> T14)
	Spectral Range		400 to 900 nm	
IMAGE FORMAT:			22.8x45.7 cm	(9x18 inches)
FIELD OF VIEW (FOV):				
	Along Track :	Degrees	73.7	(1.287 radians)
		Altitude Ratio	1.5 x H	(H = altitude)
	Across Track:	Degrees	41.1	(0.718 radians)
		Altitude Ratio	0.75 x H	(H = altitude)
FORWARD OVERLAP MODES:			80, 70, or 60 percent	
BASE/HEIGHT RATIO:			0.3 to 1.2 (over full track)	
SHUTTER:	Type		Rotary (between the lens)	
	Speeds		.006 to .024 second	
IMAGE MOTION COMPENSATION:				
	Type		Image Plane Translation	
	Range		.010 to .045 rad/sec	
FILM FLATTENING:			Vacuum	
MINIMUM CYCLE TIME:			4.3 seconds	
FILTERS:	Anti-Vignetting		Lens Front	
	Spectral		Lens Center	
FILM:	Width		24.1 cm	(9.5 inches)
	Length	Thin Base Nom.	610 meters	(2,000 feet)
		Thin Base Max.	1,220 meters	(4,000 feet)
	Exposures/Roll	Thin Base Nom.	1,200	
		Thin Base Max.	2,400	
ELECTRICAL POWER:			275 watts avg. 450 watts max.	
OPERATING PRESSURE:			1,723 N/m^2	(0.25 psi)
WEIGHT:	Large Format Camera (LFC)		230 kg	(506 lbs)
	Flight Support Structure, etc.		150 kg	(330 lbs)
		Total	380 kg	(836 lbs)

LFC IMAGING CHARACTERISTICS (TYPICAL)


STEREO BASE (B)
1
2
3
4
5
VELOCITY VECTOR
ALTITUDE (H)
74°
(41° ACROSS TRACK)

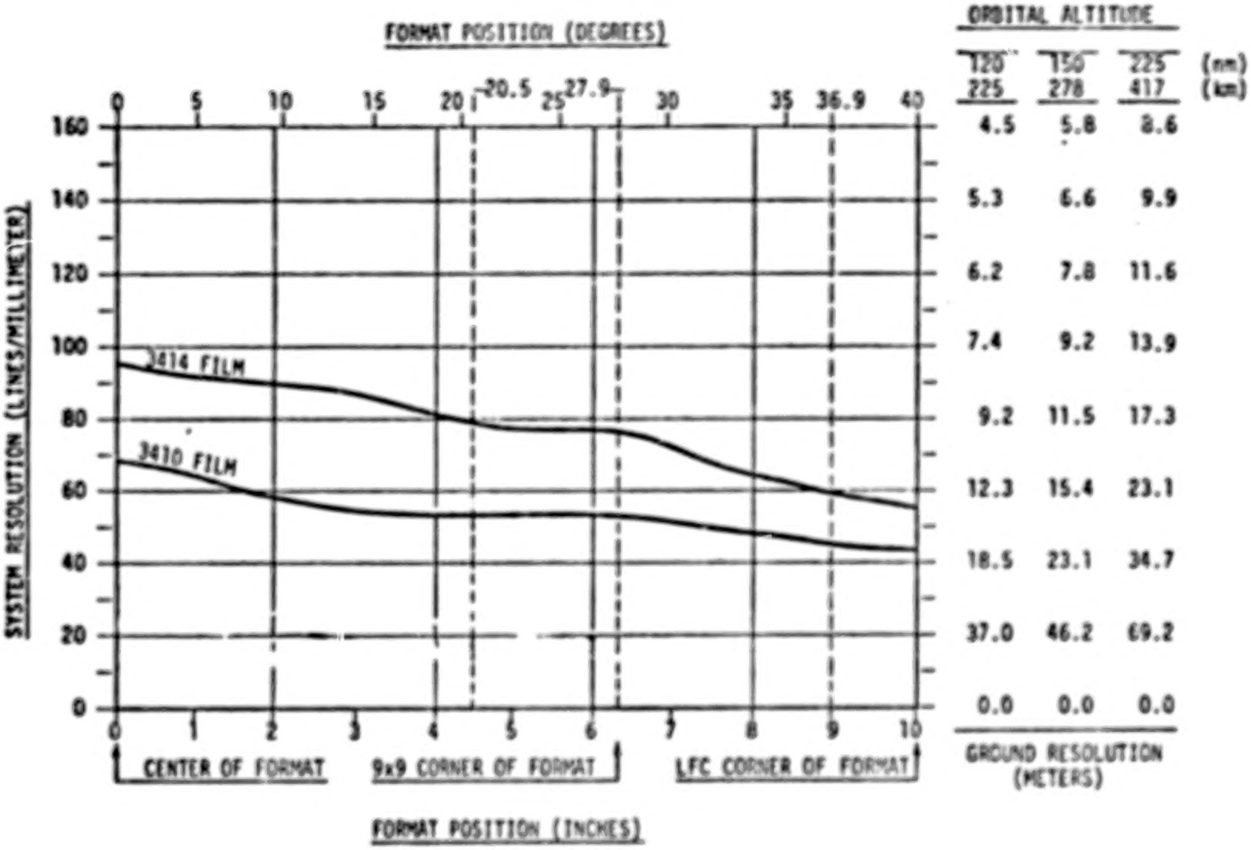
TYPICAL ALTITUDE : 278 kilometers (150 nautical miles)

PHOTOGRAPHIC SCALE : 1:912,000

GROUND FOOTPRINT : ALONG TRACK (1.50H) = 417.0 km (225 n.mi.)
ACROSS TRACK (0.75H) = 208.5 km (112.5 n.mi.)
AREA COVERED = 86,945.0 km^2 (25,312 n.mi.^{2})

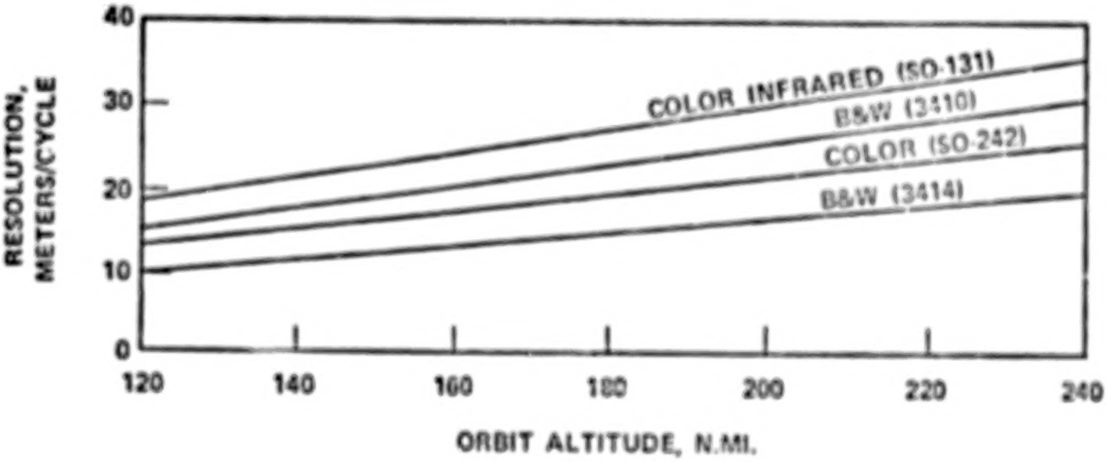
GROUND RESOLUTION (Color Film AWAR) : ~ 20 meters

PRECISION DATA REDUCTION : SELECTED FRAMES	1&2	1&3	1&4	1&5
FORWARD OVERLAP (percent)	80	60	40	20
BASE/HEIGHT (B/H) RATIO	0.3	0.6	0.9	1.2
VERTICAL EXAGGERATION FACTOR	1.4	2.8	4.2	5.5
RELATIVE POSITION ACCURACY (± meters)	14	14	14	14
RELATIVE HEIGHTING ACCURACY (± meters)	28	15	9	7



DYNAMIC GROUND RESOLVED DISTANCE

Estimated at 2:1 Contrast



HIGHLY DEPENDENT UPON SHUTTLE ATTITUDE RATES.

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Data Reduction by Computer Processing

Chairman: Dr. Dale R. Lumb
Western Regional Applications Program
NASA-Ames Research Center

Introduction

This technical workshop dealt with the subject of automated analysis of remote sensing data, specifically digital processing of Landsat or other image data in numerical form.

Two general topic areas covered in the workshop were: (1) the teaching of ditigal image processing, including both theoretical and applied subjects and laboratory experience, and (2) a review of NASA-developed image processing software, and hardware/software systems employed at NASA-Ames Research Center in support of the Western Regional Applications Program (WRAP).

The first topic was examined in a presentation by Professor Robert Schowengerdt of the University of Arizona, describing a course titled "Image Processing Lab," one of two courses required for a graduate minor in remote sensing at Arizona. A paper by Professor Schowengerdt covering the rationale, content, and hardware/software support for this course is incorporated within this section.

The review of NASA-developed software systems included presentations summarized herein by Wayne Mooneyhan of the Earth Resources Laboratory, and by Dr. Nevin Bryant of the Jet Propulsion Laboratory. Ethel Bauer of NASA-Ames described the systems at the Ames Image Processing Facility.

Finally, a questionnaire was circulated at the workshop that assessed the existing or planned digital image processing capability of the universities and colleges represented, and their interest in acquiring or gaining access to NASA-developed software. The questionnaire results are summarized at the end of the paper.

An Introductory Digital Image Processing Laboratory Course for Applications Scientists

Robert A. Schowengerdt
Assistant Professor of Remote Sensing
University of Arizona

Introduction

A new course, Image Processing Lab, was first offered at the University of Arizona in the fall semester, 1977. The course, cross-listed in the Systems and Industrial Engineering and Optical Sciences Departments, is one of two required (the other being Fundamentals of Remote Sensing) for a graduate minor in remote sensing. Because of this, the technical level and orientation of material included in the course must be such that a diverse range of graduate students will benefit from the course. Achieving a good balance between mathematical complexity and practical applications is the most challenging aspect of teaching such a course.

During the initial offering of the course, facilities available to students for image processing experiments were rather limited. There were, however, several labs and pieces of hardware around campus which were restricted to research in image processing. To expose the students to this wide variety of "real world" hardware, a series of demonstrations were scheduled throughout the semester. In general, these sessions were very well received and represented a reasonably acceptable alternative to "hands-on" experience.

Because of the shortage of interactive hardware, the course was structured much as a lecture course. In addition to the laboratory demonstrations, several computing experiments were assigned to the class. Computing was performed in a batch mode on a CDC 6400 computer with a software package of image-processing routines called SADIE. Input image files (all from Landsat imagery) were supplied by the instructor and output images were displayed by a grey shade line printer routine.

For the fall, 1978, semester we anticipate a much improved hardware and software situation. The University Computer Center has replaced the outdated CDC 6400 with a CDC Cyber 175, and a very powerful linkage of minicomputers will be operational along with an I^2S color CRT display with associated refresh memories and pipeline processor. This hardware (and an extensive set of software supplied with the CRT display) will permit a reorganization of the course to include much more extensive experimentation with image processing algorithms. Consequently, the number of formal lectures will be greatly reduced and will serve only as an introduction to each topic, with mathematical and other details covered by handouts of written material.

The enrollment in the course during the first semester consisted of the following disciplines:

Department	Number of Students
optical sciences	8
systems engineering	2
planetary science	2
geology	1
undergraduate (SE, EE)	3
unclassified graduate (medicine, hydrography)	2

The large percentage of engineering students implied a strong mathematical background for the class--94 percent had had calculus, 72 percent had had some exposure to Fourier theory, and 83 percent knew at least one programming language. Only one student had taken another image processing course and 17 percent had some experience with image processing.

The mathematical level of instruction was held to algebra, statistics (basic and multivariate), some calculus, and Fourier theory (convolution, correlation, Fourier transforms). The students with relatively poor math backgrounds were able to keep up with the rest of the class, even with the most difficult material, Fourier techniques. We wanted to achieve this, to set the pattern for the lab being an applications oriented course, even at the expense of boring more advanced students. There are several more advanced and specialized image processing courses already at the University.

We are encouraging and anticipate a much larger enrollment of students from earth sciences disciplines in the future. This will likely increase the difficulty in setting the right balance of math and applications for the course, but the availability of an interactive display and software will assist greatly in alleviating that difficulty. By having flexible image processing routines literally at their fingertips and the psychological advantage of seeing processing results almost immediately, students will obtain a good feeling for computer processing and analysis without necessarily needing to understand the mathematical aspects. Furthermore, experience with a "hands-on" system will reinforce the theoretical background of more advanced students.

The remainder of this course description is written in a modular form consisting of assorted topics and examples from the course and general aspects of teaching a course of this type. It is hoped that the brief experience reflected in this paper will be useful to those who are designing an introductory image processing course for their own remote sensing curriculum.

Course Content

Fall Semester, 1977, 3 Semester Hours Credit

Characteristics of Digital Images (about 6 lecture hours)

Radiometric quantization, relation between pixel and computer word size, quantization during image acquisition, processing, and display. Distinction between pixel size and sample interval.

Contrast Manipulation (3 hours)

Image grey level histograms, linear, segmented, cyclic, and equalization transformations.

Landsat System (3 hours)

MSS, RBV, orbit parameters, preprocessing required for image data

Neighborhood (spatial) Operations (6 hours)

Convolution, correlation, Fourier transforms, application of Fourier transforms, spatial filtering

Noise Suppression (1½ hours)

Random, fixed and variable periodic noise

Hardware Descriptions (3 hours)

Scanners and displays, microdensitometer, flying spot, vidicon, solid state arrays, electron beam recorder. Scan rate, radiometric and spatial resolution, bit rate, format size.

Geometrical Manipulation ($4\frac{1}{2}$ hours)

Coordinate transformation, tiepoints, rubber sheet stretching. Resampling by nearest neighbor algorithm and interpolation (linear, sinc function, and cubic spline function)

Multispectral Classification ($4\frac{1}{2}$ hours)

Multivariable nature of remote sensing imagery, clustering, natural variability, supervised and unsupervised classification, mathematics for maximum - likelihood algorithm

Laboratory demonstrations (6 hours)

Mirodensitometer, photographic scanner display, digitizing vidicon acquisition and display, interactive color CRT display (Kitt Peak National Observatory)

Image Processing Experiments (100+ hours)

All experiments were performed with routines in the SADIE image processing software package and were conducted by batch processing. However, some students ran so many examples that they were almost in an interactive mode! The University Computer Center charge rate was $200 per CPU hour on the CDC 6400 and the class of 18 students spent about $2,500 during the semester.

1) set up and print picture of grey scale
2) manipulate contrast of grey scale

3) calculate image histogram, contrast stretch, and display portion of Landsat image, (two bands). Investigate various contrast manipulation techniques.

4) investigate the effects of various spatial filters on portion of Landsat image.

Reference Material

There has been no text used for this course. Of the texts currently available, the one by Gonzalez and Wintz would probably be the most suitable, with the one by Pratt being similar in coverage but at a higher level of mathematics and detail. The USGS report on image processing systems is a comprehensive survey of current (1977) hardware and software for remote sensing and is highly recommended as a class handout.

Remote sensing oriented:

"Basic Mathematics of Image Processing" and "Digital Image Processing," R. Schowengerdt, Chapters XIV and XV of Principles of Remote Sensing, P. N. Slater, in preparation.

"Imaging and Nonimaging Sensors" and "Remote Sensor Data Systems, Processing, and Management," Chapters 8 and 12 of Manual of Remote Sensing, Vol. 1, American Society of Photogrammetry, 1975.

"Machine Processing of Remotely Acquired Data" and "Comparisons of Qualitative and Quantitative Image Analysis," Chapters 10 and 11 of Remote Sensing of Environment, J. Lintz and D. Simonett , eds., 1976.

Summary Tables for Selected Digital Image Processing Systems, V. Carter, F. Billingsley, and J. Lamar, U. S. Geological Survey Open File Report 77-414

General Image Processing and Analysis:

Computer Techniques in Image Processing, H. C. Andrews, 1970.

Digital Picture Processing, Rosenfeld and Kak, 1976.

Digital Image Processing, R. C. Gonzalez and P. A. Wintz, 1977.

Digital Image Restoration, H. C. Andrews and B. R. Hunt, 1977.

Digital Image Processing, W. K. Pratt, 1978.

Introduction to Statistical Pattern Recognition, K. Fukunaga, 1972.

Pattern Classification and Scene Analysis, R. Duda and P. Hart, 1973.

Perception of Displayed Information, L. Biberman, 1973.

Journals:

-Computer Graphics and Image Processing, bimonthly
-several IEEE journals, especially Proceedings, and Transactions on Computers
-J. Optical Society of America, Applied Optics, Optical Engineering
-several Proceedings of the Society of Photo-Optical Instrumentation Engineers
-"Survey-Picture Processing," A. Rosenfeld, annual bibliography, in Comp. Graphics & Image Proc., yrs. 1972-1976

SADIE and Landsat Software

The SADIE system was originally developed at the Los Alamos Scientific Laboratory and maintained at the University of Arizona by Dr. Bobby Hunt, Systems and Industrial Engineering Department. It contains a complete and thorough bookkeeping structure which keeps track of the vital parameters for input, scratch, and output files, thus freeing the user from this often laborious chore. There are two level of routines in SADIE--one line-oriented and the other file-oriented. The file-oriented routines permit a more "black-box," detached operation by the user whereas the line-oriented routines allow more complex processing by those users who need this flexibility.

Routines are available for image input and output in several formats (compatible with various hardware devices around campus), calculation of image statistics, contrast manipulation, Fourier domain spatial filtering, linear combination of images, superposition and concatenation of image files, linear image scale change, etc. Standard image display through SADIE is by grey shade line printer output (8 grey levels). Use of SADIE requires very little knowledge of Fortran and only a basic knowledge of control command setup. There was no serious difficulty in introducing students to SADIE, even those who had had no previous computer experience.

A system of software for reformatting, preprocessing, and photographic display of Landsat data has been developed by Dr. Robert Schowengerdt. This software provides an interface between Landsat preprocessed data and SADIE and scene classification software. In addition, many specialized processing routines, not available in SADIE, are operational for Landsat processing.

Exams and Handouts

This section contains copies of the two exams given during the course and a selection of external material which was distributed to the class throughout the semester. The USGS report is a good survey of operational image analysis systems and the Aviation Week article provides a discussion of current software processing tools and many color image examples. The full handouts are not reproduced here, but should be available from the original source.

OSC/SIE 236 Image Processing Lab
Mid Term Exam

October 25, 1977

Answer all questions - each worth 25 points.

1) a. If a digital image has pixels quantized to 6 bits, how many grey levels are possible? What are they?

   b. Show which bits are "on" and which are "off" for a grey level of 23.

   c. If a landsat image typically has a range of 30 grey levels, why are 64 or 128 grey levels available for the data?

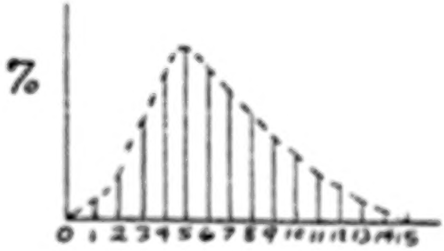
   d. Why would we desire to have more bits representing pixel values in a computer than are used for the original pixel values? Illustrate with an example.

2) a. What is a histogram of image grey levels? How is it usually normalized?

   b. Why is a histogram useful for changing image contrast? If we didn't have the image histogram what parameters of the image could be used to adjust its contrast?

   c. Why do we wish to change the contrast of an image? Describe a contrast enhancement technique which requires no operator input. Be as detailed as possible.

   d. Suppose we have an image with a histogram as follows:



   Sketch the transfer curve required to perform a simple linear "stretch" between grey levels 0 and 31 on a display. At what grey level in the displayed image would the peak of the histogram fall?

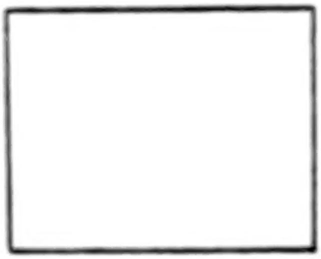
   Sketch a transfer curve which would make the peak fall at the mid-point of the display range and avoid saturation at both ends of the display range.

   In either of the above examples would all the grey levels available in the display appear in the displayed image? Explain.

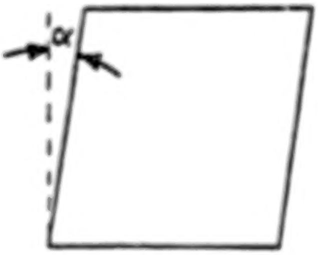
3) a. What are the spectral bands used in the Landsat MSS? Be specific.

3) b. Approximately how many pixels/line and how many lines are there in each raw Landsat image? How long is each scan line on the ground? What is the size of a pixel on the ground?

c. What are the most important preprocessing operations required for Landsat imagery? If we display a raw (unprocessed) Landsat image on a standard display we would see a format like this:



What two preprocessing operations yield a final format like this?:



How large is the angle α typically?

4) a. What is meant by a "neighborhood operation"? How is it distinct from the common contrast enhancement operation?

Name a neighborhood operation used for image processing and another used for image analysis.

b. Define a linear operation in the context of neighborhood operations. Use sketches to illustrate the definition.

How is a linear operation represented mathematically in the spatial and frequency domains? Define all symbols used in your mathematics.

Assume stationarity (shift invariance) in the above examples.

c. Why are Fourier transforms useful in an analytic sense? In a digital application?

Sketch both a high and low pass filter in the Fourier domain. What is a simple way to implement each in the spatial domain? Derive how many operations (one operation being an add, a multiply, etc.) are required per pixel in the processed image to perform this simple low pass operation with a straight-forward calculation and with a more efficient calculation utilizing temporary storage.

OSC/SIE 236 Image Processing Lab
Final Exam

December 19, 1977

Answer all questions - each worth 20 points

1) a. What is the primary source of random image noise in photography?

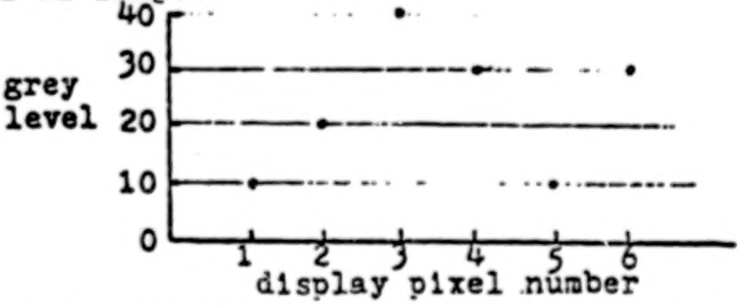
b. Briefly descibe two digital processing techniques for suppression of random noise. What is a disadvantage of each?

2) a. How is a digital image scanner's or display's bit rate calculated? What two performance measures does it combine?

b. Name an advantage which a photographic micro-writer display, such as the POD at Optical Sciences, possesses over a CRT display, such as the one at Kitt Peak? What advantage does the CRT have over the POD?

3) a. What are the two steps required for geometrical manipulation of digital images?

b. Suppose the graph below represents a line profile through a digital image:



We want to magnify the image digitally to contain 9 pixels in the line instead of 6. Tabulate all the pixel values in the processed line and make a graph like that above for the:

1-nearest neighbor algorithm
2-linear interpolation algorithm

Note the display pixel interval is fixed.

c. Name an advantage and a disadvantage of cubic spline versus linear interpolation.

4) a. What are the three dimensions of multispectral imagery? In which dimension does multispectral classification work?

OSC/SIE 236 Image Processing Lab December 19, 1977
Final Exam

4) b. In two or three paragraphs, explain how multispectral classification is performed. You do not need to be specific about particular algorithms, etc.

c. List and briefly explain three sources of natural variability in classification analysis.

5) a. Suppose we have a study area on the ground which is 40km x 40km large. One of the Landsat satellites takes an image of the area every 9 days. If we must make a decision about each pixel in the study area (for example, assign each pixel to a vegetation class) from one image before the next image is taken, how much time do we have, per pixel?

b. If a single Landsat MSS acquires 10 scenes per day, what is the data creation bit rate?

May 1977

SUMMARY TABLES FOR SELECTED DIGITAL IMAGE PROCESSING SYSTEMS

by

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Open-File Report 77-414

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LANDSAT MULTISPECTRAL SCANNER SYSTEM

Nominal Orbital Altitude 915 km

Scanner

Telescope optics	22.9 cm aperture Ritchey-Chretien with 8.9 cm aperture secondary mirror
Focal length	82.6 cm
F-number	3.6
Scanning method	Oscillating flat mirror ±2.9° at 13.62 Hz
Cross-track field-of-view	11.6°
Scan duty cycle (active scan)	31.5 ms of 73.42 ms cycle minimum (43% active scan time)
Optical fiber core	70.9 μm side of square
Instantaneous field-of-view	0.086 mr
Spectral bands and detectors (bands 4 - 7 respectively)	0.5 - 0.6 μm photomultiplier tube 0.6 - 0.7 μm photomultiplier tube 0.7 - 0.8 μm photomultiplier tube 0.8 - 1.1 μm silicon photo diodes
Number of lines scanned/scan/band	6
Area of fiber optics array	396 μm along track x 432 μm across track
Geometrical projection of square side of fiber core (pixel) onto ground	79 m
Gap between pixels cross-track	6 m
Sampling distance	56 m
Video bandwidth (-3 dB)	42.3 kHz per channel

Radiometric Quantities

Optical transmittance including secondary mirror obscuration	0.26
Radiance $Wm^{-2}sr^{-1}$ at entrance pupil to produce full scale output and signal-to-noise ratio. Note these values are for Landsat 1, they are different for Landsat 2.	24.8 Band 1 112:1 20.0 Band 2 86:1 17.6 Band 3 72:1 46.0 Band 4 122:1

Multiplexer

Number of channels	24
Quantization	6 bits (64 shades of grey)
Quantization accuracy	Within ±30 mv at any quantum level
Processing modes	Linear and signal compression
Clock stability	±1 part in 10^4 over a year
Output bit rate	15.06 x 10^6 bps
Sampling rate each channel	100,418 samples/9.96 MHz
Crosstalk	>40 dB rejection

LANDSAT MULTISPECTRAL SCANNER SYSTEM
Concluded

Interface Parameters

Scanner weight	47.6 kg
Multiplexer weight	2.7 kg
Scanner size	Approx. 36 x 38 x 90 cm
Multiplexer size	10 x 15 x 17 cm
Regulated power, -24.5 v	20 W scanner, 19.6 W multiplexer
Unregulated power, -39 v	22 W
Command capability	72 (SS assigned)
Telemetry channels	97

Reflections on Course Content and Plans for the Future

At this point I would like to pass on some experiences with the Image Processing Lab Course and some personal opinions about what such a course should contain. A brief discussion will then be given on how the course will be restructured this year because of the acquisition of a considerable amount of interactive image processing hardware.

Perhaps the most difficult material to present in the course is that on convolution, Fourier transforms, etc. Even though most of the students were engineers and had seen this subject before, it had evidently not been from a primarily implementation/application viewpoint. To de-emphasize the more complex concept of Fourier transformation and because much practical spatial filtering is performed in the spatial domain, I introduced filtering from the spatial domain. This was done by describing simple box arrays which are convolved with the image to perform filtering. Examples of these arrays might be,

smoothing (low-pass)

1	1	1
1	1	1
1	1	1

edge enhancement (high-pass)

-1	-1	-1
-1	8	-1
-1	-1	-1

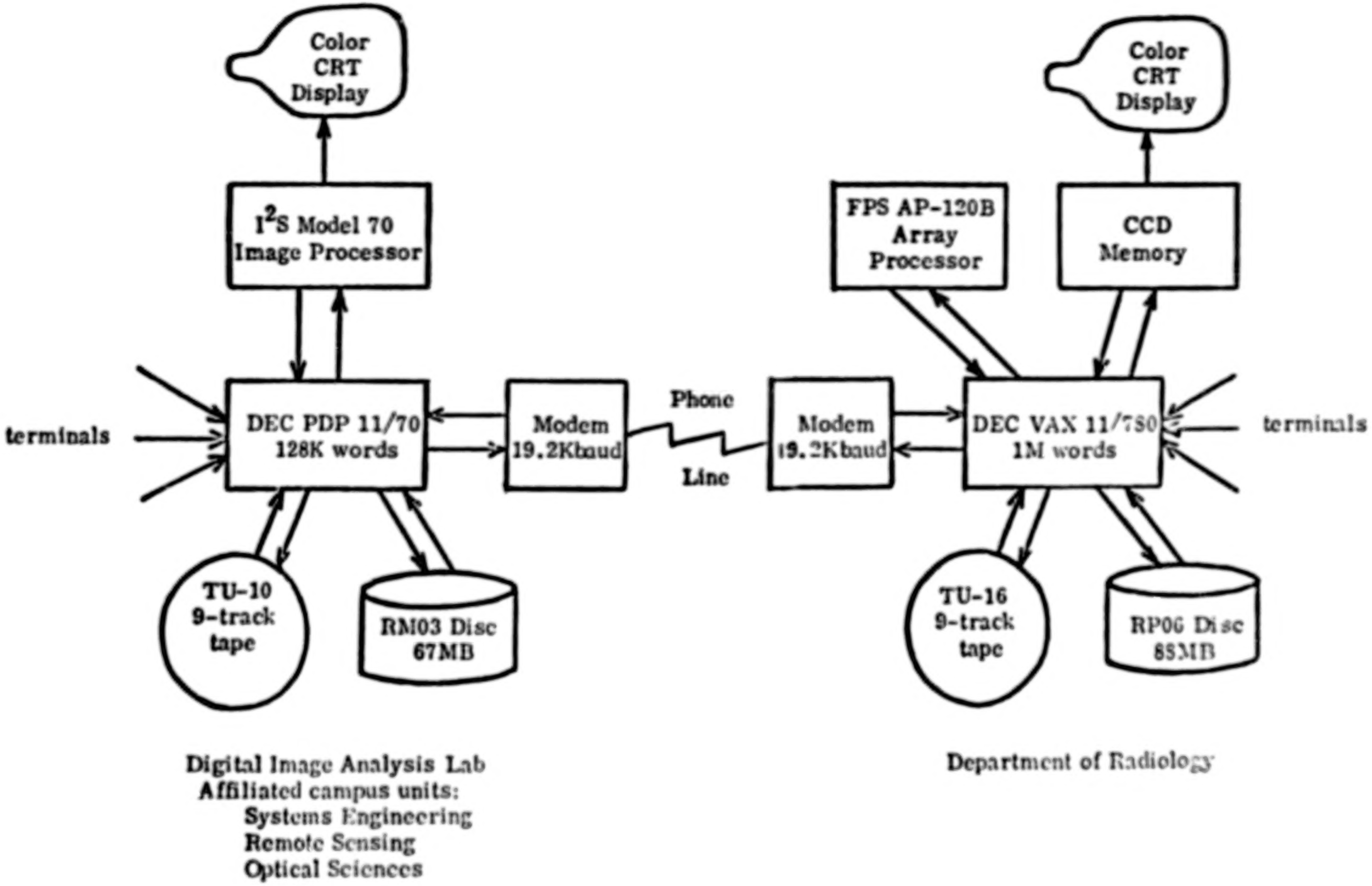
From these most basic examples, a smooth transition can be made to discussion of more complex filters with variable weights, non-square filters, inclusion of normalization in the weights, etc. After a review of basic Fourier transformation, these spatial arrays can be described in general terms in the Fourier domain. This approach was intuitively satisfying to the students and is appropriate for an introductory course.

As an aid to discussion of Fourier transforms, we devoted half of one lecture period to a demonstration with an electronic waveform generator, spectrum analyzer, and oscilloscope. A very visual illustration can be made with this equipment by demonstrating the Fourier domain representations of sine waves, square waves, etc. and the effect in the Fourier domain of variation in the waveform period and amplitude. More comprehensive displays can be done by adding another waveform to the original and by inserting a variable electronic filter in the circuit. Such a demonstration could also be easily done with an interactive graphics terminal and digital transform algorithms.

Another rather difficult topic, which is quite often neglected in image processing courses, is geometrical manipulation. This subject should be part of any remote sensing oriented image processing course because of the increasing interest in precise mapping from orbital (or aerial) images and the greater capabilities of future sensors. I was surprised that it was as difficult as it was to communicate this subject to the students. Even though most of the students were second or third year engineering graduate students, they, for the most part, had little experience with interpolation of discrete data and in particular the connection between interpolation and convolution. In the future, more time will have to be devoted to these areas to treat the subject properly. Again, an interactive image (or graphics) display will be an efficient tool for illustrating geometrical processing.

This Lab will be taught again in the fall, 1978, and will be oriented around the digital image display available at that time. The series of hardware demonstrations will be retained since they are still very important in their own right. Formal lecture time will probably be reduced by a factor of about two, with the remaining class time filled by demonstrations on the display. Students will have additional allotted time periods during which they can operate the display and computer either alone or in small groups. Software details will be essentially transparent to the users and menus of processing options will be available. The more sophisticated students will be able to program their own software on the host computer (PDP 11/70). A schematic of the interactive facility is shown in the diagram below.

The subjects covered in the course will probably be changed very little, with some shifting of emphasis from topic to topic based on the first semester's experience. Scene classification experiments will be greatly facilitated by the new hardware and software and will occupy a larger proportion of the course.


Color CRT Display
I²S Model 70 Image Processor
terminals
DEC PDP 11/70 128K words
Modem 19.2Kbaud
Phone Line
Modem 19.2Kbaud
DEC VAX 11/780 1M words
terminals
FPS AP-120B Array Processor
CCD Memory
Color CRT Display
TU-10 9-track tape
RM03 Disc 67MB
TU-16 9-track tape
RP06 Disc 88MB
Digital Image Analysis Lab
Affiliated campus units:
Systems Engineering
Remote Sensing
Optical Sciences
Department of Radiology

U. Arizona Interactive Image Processing Hardware
Fall 1978

Image Processing Software/Systems Developed or Employed by NASA

Earth Resources Laboratory Software for Modular Systems

NASA-ERL at Slidell, Louisiana has developed a low-cost, modular approach to the design of data analysis systems for processing Landsat or other multispectral image data.[1] It is aimed at the small user organization having limited funds and access to some computer equipment. As described by Wayne Mooneyhan of ERL, this approach consists of a definition of equipment configurations that take advantage of existing or off-the-shelf hardware components available to many users, plus a set of ERL-developed software modules for image processing, geographic data manipulation, data base management, and applications-specific information extraction.

As shown in Figure 1, hardware requirements are defined in terms of the three basic components: (1) an image display device, (2) a computer with appropriate peripherals, and (3) an output recording device.

A display device desirably consists of a color-CRT monitor with interactive uer interface, however, hardcopy devices such as line-printer or electrostatic printer/plotters can be used with batch programs for data display. A color display is advantageous for review of raw input data, training site entry, and evaluation of test classifications of small (screen-size) areas, and can be used in a time-sharing environment.

Any mini or larger general purpose digital computer can serve as a central processor, provided it has at least 130K bytes of memory, two tape drives, 24M bytes of disc memory and a Fortran compiler.

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LOW-COST SYSTEM COMPONENTS

DISPLAY SYSTEM	COMPUTER	OUTPUT RECORDING DEVICE
ANY OF SEVERAL COMMERCIALLY AVAILABLE TV IMAGE DISPLAY DEVICES --COMTAL 8000 SERIES --HAZELTINE --RAMTEK --ETC.	ALMOST ANY DIGITAL MINI- OR LARGER COMPUTER WITH 130K BYTES MEMORY TWO TAPE DRIVES 24M BYTES DISK MEMORY FORTRAN COMPILER OPERATING EXECUTIVE --PERMITTING MULTI-TASK OPERATION	ELECTROSTATIC PRINTER-PLOTTER --STATOS (VARIAN GRAPHIC) --GOULD (DEC PDP-11) --VERSATEK --ETC. FILM RECORDERS --DICOMED --OPTRONICS --HRB-SINGER

SUPPORT DEVICES

VACUUM FRAME PRINTER PHOTO-PROCESSING SINK AND WATER	DARK ROOM
CROMALIN LAMINATOR CROMALIN TONING CONSOLE	NORMAL ROOM LIGHT

Figure 1

In addition to a conventional lineprinter for running tabular or alphanumeric-symbol output, a recording device for production of map products is desirable. This can consist of an electrostatic printer/plotter or dot-matrix printer for gray-scale maps, or a film recorder for color-coded maps. Electrostatic printer/plotters can be programmed to produce three gray-scale plots representing the red-green-blue components of a color-coded classification, and these can be used as color separations in a lithographic printing process such as "Kwik-Proof," or a photographic process such as "Chromalin." These methods avoid the need for a color film recorder, which is an expensive, specialized equipment item.

The ERL software consists of some 100 Fortran IV programs available from COSMIC and described in a digest of program abstracts.[2] The programs are grouped into software modules. Figure 2 is an overall view of the processing functions performed by these modules, which include: (1) pattern recognition (conversion of raw Landsat MSS data and other supporting data to surface classification maps); (2) geographical reference of Landsat-derived data (pixel-to-UTM coordinate conversion); (3) data base storage and retrieval of Landsat-derived and other geographic data (up to 30 bytes of information for each 400-meter^2 or quarter-section unit for an entire state, using either UTM-gridded or Public-Land Survey-referenced units, respectively – see Figure 3); and (4) information extraction combining Landsat-derived and other data for specific management applications (e.g., combining land cover, slope, aspect, soil series, and rainfall in an assessment of erosion hazard). Figure 4 shows capabilities of processing routines within these modules.

LANDSAT BASED
INFORMATION SYSTEM SOFTWARE-OVERALL VIEW

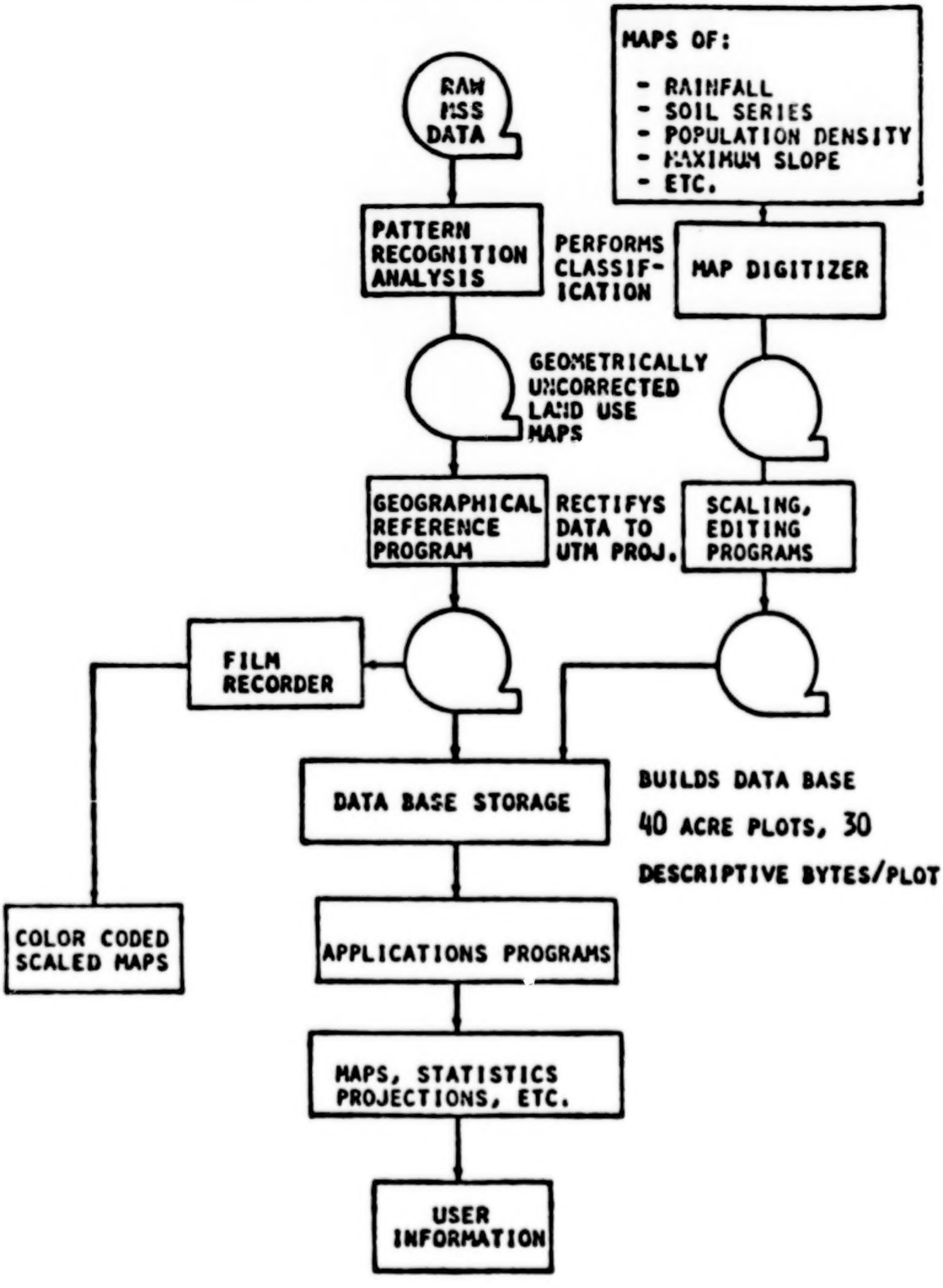

RAW MSS DATA
MAPS OF:
- RAINFALL
- SOIL SERIES
- POPULATION DENSITY
- MAXIMUM SLOPE
- ETC.
PATTERN RECOGNITION ANALYSIS
PERFORMS CLASSIFICATION
MAP DIGITIZER
GEOMETRICALLY UNCORRECTED LAND USE MAPS
GEOGRAPHICAL REFERENCE PROGRAM
RECTIFYS DATA TO UTM PROJ.
SCALING, EDITING PROGRAMS
FILM RECORDER
DATA BASE STORAGE
BUILDS DATA BASE
40 ACRE PLOTS, 30 DESCRIPTIVE BYTES/PLOT
COLOR CODED SCALED MAPS
APPLICATIONS PROGRAMS
MAPS, STATISTICS PROJECTIONS, ETC.
USER INFORMATION

Figure 2

FOUR DATA BASES: 30 BYTES PER CELL

a) W of 90° b) E of 90°

8 BIT BYTE	GRIDDED	NON-GRIDDED
1. 2.	township number	township number
3. 4.	unused	forty number
5.	county number	county number
6.	section number	section number
7.	drainage	drainage
8.	ownership	ownership
9. 10.	column number	easting offset in 20 m. units of center of forty
11. 12.	row number	northing offset in 20 m. units of center of forty
13.	land use base	land use base
14.	surface features (fall)	surface features (fall)
15.	(winter)	(winter)
16.	(spring)	(spring)
17.	(summer)	(summer)
18.	(temporary)	(temporary)
19.	soil series	soil series
20.	slope (average)	slope (average)
21.	slope (maximum)	slope (maximum)
22.	elevation	elevation
23.	aspect	aspect
24.	accessibility	accessibility
25.	terrain	terrain
26.	population density	population density
27.	rainfall (highest avg. month)	rainfall (highest avg. month)
28.	unused	unused
29.	unused	unused
30.	unused	unused

NOTES:

1) Establish 62 permanent classes + unclassified. (See note 4.)
2) Maximum capacity: 1 byte = 254; 2 bytes = 32,767. (See note 4.)
3) Missing flags: 1 byte = 255; 2 bytes = -1
4) Zero is reserved to indicate unchanged.
5) Unused fields are indicated as missing.

Figure 3

EXISTING SOFTWARE CAPABILITIES

- LANDSAT DESTRIPING
- AUTOMATED SIGNATURE DEVELOPMENT (Program SEARCH)
- MANUAL SIGNATURE DEVELOPMENT (GROUND TRUTH, MANUAL SELECTION, STATS EVALUATION)
- CLASSIFICATION - MAXIMUM LIKELIHOOD RATIO, SEVERAL EFFICIENT IMPLEMENTATIONS
- DATA OUTPUT PREPARATION - SCALING, COLOR OR GRAY-SCALE ASSIGNMENT
- GEOGRAPHICAL REFERENCE CONVERSION - TO UTM
- MULTISCENE OVERLAY
- DATA BASE STORAGE AND RETRIEVAL
  - —GRIDDED (50M x 50M) TO (400M x 400M)
  - —NON-GRIDDED - REFERENCED TO PLS SYSTEM
- APPLICATION ALGORITHMS
  - —ACREAGE WITHIN A POLYGON
  - —WILDLIFE HABITAT ASSESSMENT
  - —CROP PRODUCTION ESTIMATE
  - —EROSION HAZARD ASSESSMENT
  - —SITE EVALUATION
  - —SOIL ASSOCIATION
  - —CHANGE DETECTION
  - —WATER SEARCH
- UTILITY ROUTINES

Figure 4

422

COMPUTERS ON WHICH EXISTING SOFTWARE HAS BEEN IMPLEMENTED

COMPUTER	INTERACTIVE PROGRAMS	BATCH PROGRAMS
UNIVAC V-70 SERIES (VARIAN DATA SYSTEMS)	X	X
INTERDATA 8-32	X	X
UNIVAC 1108		X
IBM 370-155		X
SEL 16-BIT		X
SEL 32-BIT		X
NOVA II	X	X

NOTE: THE FULL CAPABILITY OF PROCESSING LANDSAT MSS DATA FROM RAW DATA TO GEOGRAPHICALLY REFERENCED MAPS AND DATA PRODUCTS EXISTS IN EITHER BATCH PROGRAMS OR BATCH/INTERACTIVE PROGRAMS

Figure 5

DATA ANALYSIS SYSTEM OPTIMIZATION HISTORY

EARTH RESOURCES LABORATORY

HARDWARE

Year	Components	Cost
1972	Data Analysis System, Univac 1108	$1M + cost of U-1108
1976	Image Display/Minicomputer/Output Recorder	$150K

SOFTWARE

CLASSIFIERS (Based on Maximum Likelihood Ratio)

Year	Program	Computer Time to Classify One Landsat Scene		Cost Per Landsat Scene	
		U-1108 (CPU)Hrs.	Varian V75 Mini (Wallclock) Hrs.	U-1108	V-75
1971	LARSYSAA	22.5	---	$11,250	
1972	Digital Table Lookup	2.3	---	1,150	
1974	ELLTAB	1.2	---	600	
1975	ELLTAB	---	2.0		$100
1976	MAXL4	---	1.5		75
1978	MAXL4X	.33	.66	167	35

Blanks indicate no implementation for this timeframe

GEOGRAPHICAL REFERENCE (To UTM Projection)

Year	Program	Minicomputer	Run Time (Wallclock Hrs.)	Cost/Frame
1975	GEOREF	Varian 75	5.0	$250
1977	GEREF4* (1°x1°area)	Varian 75	3.0	150
1978	SUPERG* (Full Frame)	Varian 75	.9	45

*Accuracy improved by application of mirror scan speed correction

Figure 6

This software was originally developed for a Univac 1108 computer, and later, a Varian V-70 series mini, however it is transportable to other Fortran machines as shown in Figure 5. Figure 6 shows ERL's history of system optimization as a result of the shift to minicomputers and the development of more efficient programs. Dramatic reductions are seen both in hardware cost and CPU time/cost to perform major imag processing tasks such as full-scene, maximum-likelihood classification and geographic reference.[3]

Jet Propulsion Laboratory VICAR/IBIS Software System

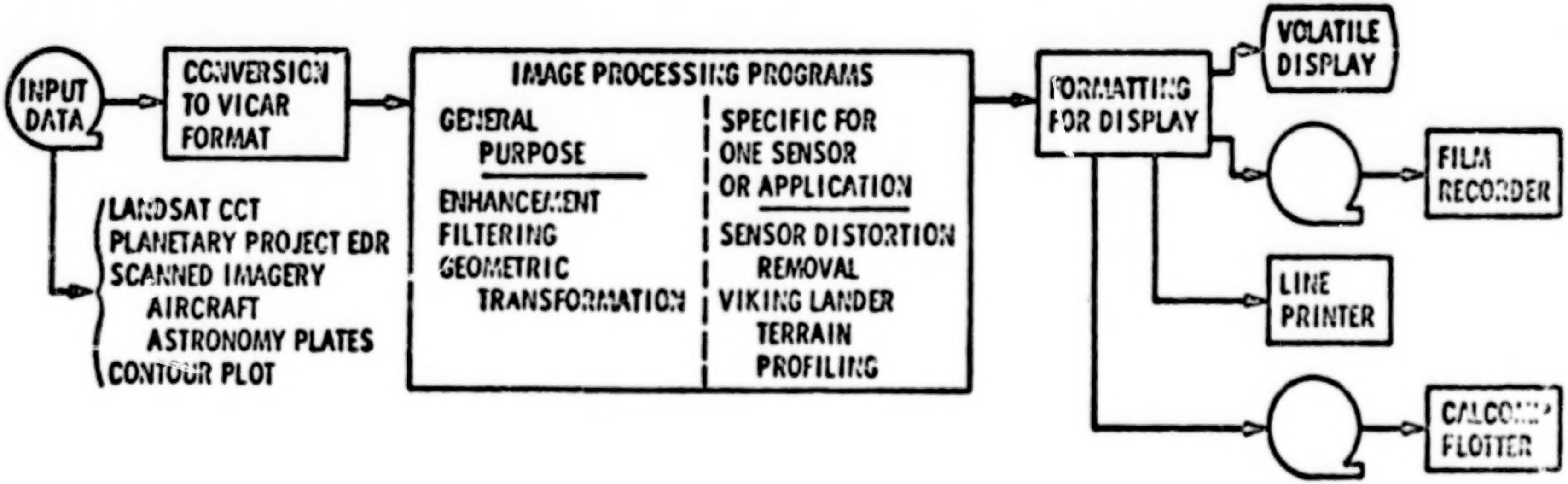
JPL at Pasadena has been involved in digital image processing for over a decade, starting with development of enhancement techniques for vidicon pictures returned from the early unmanned planetary flights of the 1960's. Out of this experience the JPL Image Processing Laboratory has developed VICAR (Video Image Communication and Retrieval), a general-purpose image processing software system that incorporates many types of processing functions applicable to image data from a variety of remote sensor sources, including Landsat data and digitized photographic imagery. Major types of processing functions include contrast manipulation, multispectral band ratioing, and multispectral classification. Several kinds of geometric transformations are possible, including correction of systematic distortions, transformation to a map projection, and multiple image registration. These spatial/radiometric transformations are based on interpolation ("rubber-sheet") techniques applied to the correspondence of selected tiepoints within specified input and output images.

A further development is IBIS (Image-Based Information System), a set of processing routines designed to combine remote-sensing-derived image data with other geo-coded data sets through conversion to a common raster format, such as that represented by Landsat pixels. IBIS permits efficient registration and cross tabulation of two or more data sets, regardless of the source, scale, or format of the original data. Although IBIS consists of a set of routines that were added to VICAR, the concept of an image-based information system is far-reaching, and the VICAR image processing functions may be viewed as one component that applies to certain remote-sensing-derived data sets within a larger information structure.

VICAR. VICAR consists of a language translator that simplifies execution of image processing programs, a series of applications programs that include capabilities mentioned above, and a series of modular subroutines used for data input/output, program parameter input, and other functions. Generalized software components of VICAR are shown in Figure 7.

The system operates under the standard IBM OS/MVT operating system and is resident at JPL on an IBM 360/65 with one megabyte of core and interfaces to a large number of disks and tape drives to accommodate the large files associated with image processing technology.[4] Numerous other peripherals are used for I/O including digitizers, plotters, and film recorders. Much of the system is operational in either batch or interactive mode; however, most use to date has been batch. THE VICAR system software, consisting of modular FORTRAN programs, is most readily transferable to a batch system.

JPL VICAR IMAGE PROCESSING SYSTEM
SOFTWARE COMPONENTS



INPUT DATA

- LANDSAT CCT
- PLANETARY PROJECT EDR
- SCANNED IMAGERY
  - AIRCRAFT
  - ASTRONOMY PLATES
- CONTOUR PLOT

CONVERSION TO VICAR FORMAT

IMAGE PROCESSING PROGRAMS

GENERAL PURPOSE	SPECIFIC FOR ONE SENSOR OR APPLICATION
ENHANCEMENT FILTERING GEOMETRIC TRANSFORMATION	SENSOR DISTORTION REMOVAL VIKING LANDER TERRAIN PROFILING

FORMATTING FOR DISPLAY

VOLATILE DISPLAY
FILM RECORDER
LINE PRINTER
CALCOMP PLOTTER

VICAR's language translator, VTRAN, enables a user who may not be familiar with computer languages to perform complex image processing tasks using a simple control language. A typical VICAR control statement might be the following:

```
EXEC,STRETCH,A,B(300,400,200,200),(LINEAR,34,178)
```

This statement will execute the program STRETCH to perform a linear contrast enhancement of an image on data set A, starting at line 300, sample 400. The end points of the linear stretch will be 34 and 178 DN (gray scale values), and the output (stretched) image will be placed in data set B.

Other straightforward commands exist in the VICAR syntax to allocate data sets on disk or tape, to add annotation to hardcopy imagery, and to perform other general-purpose functions. The VTRN translator converts VICAR syntax into the appropriate job control language actually used in executing particular tasks.

The VICAR system is modular, and sequences of execute statements may be defined to perform sequential operations on digital imagery. For example, a typical Landsat processing sequence might include execution of a logging program to convert the raw image into VICAR format, a geometric transformation to remove skew, a high pass filter to accentuate local detail, a contrast enhancement of the filtered, deskewed image, and execution of a program to write the processed image onto tape for playback on a digital film recorder.[5]

It is normally necessary to write only one program that operates at the front end of a processing sequence - the logging program that converts the image from its original format to VICAR format. Once this conversion has been performed, the image in VICAR format, on disk, can then be processed by any of the general purpose routines in the program library.

The VICAR system presently has over 100 routines for image manipulation. A list of these routines and a classification of them by function is given in Tables 1a and 1b. Note the algorithms available for multispectral classification, which include a Bayesian (maximum likelihood) classifier, BAYES, and a hybrid classifier, FASTCLAS, which uses a high-speed distance algorithm to assign most of the data, but brings in a Bayesian algorithm in cases of high uncertainty. VICAR has mainly been used in a supervised clustering approach where the analyst sets up each spectral class by submitting training sites. An unsupervised clustering routine has also been developed, however. The STATS routine outputs cluster means and variances, as in other systems.

IBIS. The initial motivation for JPL's development of IBIS was to permit processing of a Landsat thematic map showing land cover in conjunction with a census tract polygon file, to produce a tabulation of land use acreages per census tract. An analysis of the steps necessary to achieve this capability indicated that a large number of image processing and data manipulation capabilities would be needed for even the simplest case, but that with proper design these capabilities could be extended into a general information system with unique attributes. The term Image Based Information System was adopted because the image datatype and image processing operations are central to many of the potential capabilities. Until recently, the image format has been viewed primarily as a computer processable equivalent of a photograph, with the value stored in each cell or

Table 1a

VICAR ROUTINES

ANNOTATION	ARITHMETIC FUNCTIONS	ARTIFACT, BLEMISH & NOISE REMOVAL	CONTRAST ENHANCEMENT	DATA FILE GENERATION	DATA TRANSFER	DISPLAY	FOURIER TRANSFORM
MARK	DIFFPIC	ADESPIKE	ASTRTCH2	CCOPY	INSECT	ASTRTCH2	FFT1
MASK	F	DESPIKE	EXPAND	RES75	INSERT	DNSYMBOL	FFT1PIX
TEXTAD	F2	DESTRIPE	F	SOSGEN	SAR	FOTO	FFT2
	FFT2	REPAIR	F2	VLOGLSF	VCOPY	LPLOT	FFT22
	PICAVE	RESREM	FOTO		VSAR	LPLOT2	FFTFIC
	PIXH	SAR	LINEAR			MASK	FFTPIC
	RATIO		MASK			MASK76	POWER
	XFORM		MASK76			OPMASK	SPIKMASK
			RDISPLAY			PRINTPIX	
			STRETCH			RDISPLAY	

GEOMETRIC TRANSFORMATION	HISTOGRAM GENERATION /DISPLAY	IMAGE MOTION COMPENSATION	IMAGE REGISTRATION	IMAGE STATISTICS	IMAGE SUB-SET MODIFICATION	JOB FLOW MONITOR & CONTROL	LABEL MANIPULATION & LISTING
ASPECT	ASTRTCH2	SMEAR75	PICREG	EIGEN	PSAR	CORETEST	LABCAT
C130RECT	FOTO		RANGER	HISTGEN	QSAR	MSG	VCOPY
EXPAND	HISTGEN		STERGEN	LAVE	SAR		VERTSLAB
FLOT	HISTSAVE			LIST			VLABEL
GEOM	LIST			LPLOT			
GEOMA	MASK			LPLOT2			
INTERP	MASK76			PIXSTAT			
LGEOM	RDISPLAY			POWER			
MAGNIFY				PRNT			
MAP2				STATS			
PIXPIK							
POLARECT							
SIZE							

Table 1a (con't)

MOSAIC MULTIPLE DATA SETS	MULTI-IMAGE TRANSFORMATION	MULTI SPECTRAL CLASSIFICATION	NON-IMAGE DATA MANIPULATION	NON-VICAR	PLOTTER DISPLAY	PREDISPLAY	PROCEDURES & MACRO
CONCAT	COLOR1	BAYES		MORTRAN2	LPLOT	ARROW	CRASS
FASTMOS	COLORASM	ERROR			POWER	EXPAND	EVIL2
INSECT	EIGEN	FASTCLAS				INSECT	VOMTF
MOSAIC	F	SIMPLIFY				LPLOT2	
NEWMOS	F2	STATS				OPMASK	
	XFORM	UNCL				PIXPIK	
						PSAR	
						QSAR	
						RESAMP	
						TEXTAD	

REFORMATTING	SPATIAL FILTERING	SYNTHESIS & SIMULATION	SYSTEM LEVEL	TAPE MOUNTING & POSITIONING	TIEPOINT GENERATION OR TRANSFORMATION	TRANSFER FUNCTION COMPENSATION	BATCH
FORGRE	AFILTER	F	LIBEXEC	ADDON	PHOTOGM	FICOR	
MSS	BOXFLT	F2	TAPE2	VMOUNT	POLYGEOM	GEOCAM	
VERTSLOG	BOXFLT2	GEN	VICARDSN	VREWIND	TPTCAT	GEOTRAN	
VLLOG	FASTFIL1	PIXH	VMAST		TPTRRNCH	OTF1	
VOLOG	FASTFIL2	PSAR	VMIO		TPTSWTCH	OTF2	
VSAR	FILTER	QSAR	VTRAN			RADCAM	
	FILTER2	VGEN				RESEAU75	
	MEDIAN					SMEAR75	
	SIMPLIFY					SOS	

INTERACTIVE	OTHER
LIBEXEC	

Table 1b

Classification and Functions of VICAR Routines

CLASSIFICATION	FUNCTION
1) Annotation	provide annotation on image
2) Arithmetic functions	arithmetic combination of image data sets and/or numerical data sets
3) Artifact, blemish & noise removal	remove unwanted data from image
4) Contrast enhancement	self explanatory
5) Data file generation	generate files of data for access by subsequent programs
6) Data transfer	transfer data from one storage medium to another, or one data set to another
7) Display	format for display
8) Fourier transform	transform image to and from, or operating on image in, the Fourier Transform domain
9) Geometric transformation	change spatial characteristics of image
10) Histogram generation/display	generate and display histogram
11) Image motion compensation	remove smearing due to image motion
12) Image registration	geometrically register multiple images
13) Image statistics	collect, extract, and/or display statistics of data comprising an image
14) Image sub-set modification	modifies or operates on sub-set of image
15) Job flow monitor and control	self explanatory
16) Label manipulation & listing	create, modify or display label on VICAR data set
17) Mosaic multiple data sets	assemble several data sets into single data set

Table 1b (con't)

CLASSIFICATION	FUNCTION
18) Multi-image transformation	transform multiple images into another domain
19) Multi spectral classification	identify regions of an image which have common characteristics in multiple data planes
20) Non-image data manipulation	manipulate data which are in non-data format
21) Non-VICAR	do not require VICAR format
22) Plotter display	generate a CALCOMP plot tape output
23) Predisplay	combine, re-orient, reformat, or annotate for display
24) Procedures & macro	assemblage of programs
25) Reformatting	transform data sets from one format into another
26) Spatial filtering	self explanatory
27) Synthesis & simulation	create image or simulate scene
28) System level	system nature as opposed to applications
29) Tape mounting & positioning	self explanatory
30) Tiepoint generation or transformation	
31) Transfer function compensation	remove intervening transfer function
32) Batch	program operates in batch mode only
33) Interactive	program operates in interactive mode only
34) Other	

pixel of the image representing a gray level or color. But if the image represents a geographic area, the value in the pixel can be a datum for the area corresponding to that pixel. A principal advantage of image representation is that data for a geographic point can be accessed immediately by position in the image matrix.

The basic premise of IBIS, then, is that existing geocoded data of any type can be referenced to an image raster scan that is equivalent to an ultra-fine mesh grid cell data set. There is no loss of special resolution as is often the case with conventional large-grid-cell geocoding systems. If this raster scan corresponds to that of image data from a remote sensor, or its derivative (e.g., a thematic map), then digital image processing techniques can be applied to interface the existing geocoded data and the remote-sensing-derived data. More than simply a means of introducing remotely sensed imagery into geographic data processing, this offers a new approach to the management and analysis of all spatially-referenced data.

An image-based information system resolves several of the difficulties of combining in one system ordinal (geographic-coordinate) and nominal (district-referenced) information, and of handling tabular, graphical, and image data types. This is possible because of the versatility of the image data type, which can serve several purposes, for example:

Physcial Analog: The pixel value represents a physical variable such as elevation, rainfall, pollutant level, etc.

District Identification: The pixel value is a numerical identifier for the district which includes that pixel area.

Class Identification: The pixel value is a numerical identifier for land use, land cover, or any other area classification scheme.

Tabular Pointer: The pixel value is a record pointer to a tabular record which applies to the pixel geographical area.

Point Identification: The pixel value identifies a point, or the nearest of a set of points, or the distance to the nearest set of points.

Line Identification: The pixel value identifies a line, or the nearest of a set of lines, or the distance to the nearest of a set of lines.

In addition, certain pixels can serve as tie-points for the registration of multiple sets of image data, or for translating any data set into the geographic coordinates of a particular mapping system.

The image format of data sets is conducive to efficient handling of many of the spatial and geometric calculations which may need to be performed on multiple geocoded files for analytical or modeling purposes. For example: (1) Given a district file and an area classification file, what are the acreages of each classification in each district? (2) Given two district files, one major and one minor, what are the proportions of each minor district in each major district? (3) Given a district file and a line segment, what is the length of the line segment in each district? Many such operations are difficult and time consuming if the working data base is in polygon or graphical format (lines specified by their end points, and districts given by a sequence of line segments). In particular, the operation called "polygon overlay" which solves (1) and (2) is extremely unwieldy for large files in graphical format.

If the files are in image format, then polygon overlay becomes a simple counting operation (Figure 8).

An operation of special importance is crosstabulation, the conversion of data aggregated by one district convention to an aggregation by another district convention. The operation involves multiplying by a set of factors which measure the percentage sub-areas of one districting in the other. The crosstabulation factors are derived by polygon overlay and may also be modified by a density estimate of the variable being crosstabulated. An example of this using IBIS was the Pacific Northwest Portland Urban Project in which Landsat-derived land cover data was tabulated by census tracts, traffic zones used in a transportation model, and 2-km grid cells used in an air quality model. Because census data (population) was available for one of these district units (census tracts), a population coefficient could be derived for the pixels of each land cover class within each census tract, based on the observed distribution of land cover. These pixel coefficients could then be used to crosstabulate the census data by traffic zones and 2-km grid cells as required for input to the analytical models.[6]

Because the image data type is used, capabilities for digital image file handling, image manipulation, and image processing are required. Thus, IBIS was built upon VICAR, the existing image processing system. Certain basic image processing operations are essential. One must accomplish image-to-image registration, whereby images of different scale, rotation, or map projection are superimposed precisely enough so that corresponding pixels represent the same geographic location. "Rubber-sheet" registration is almost

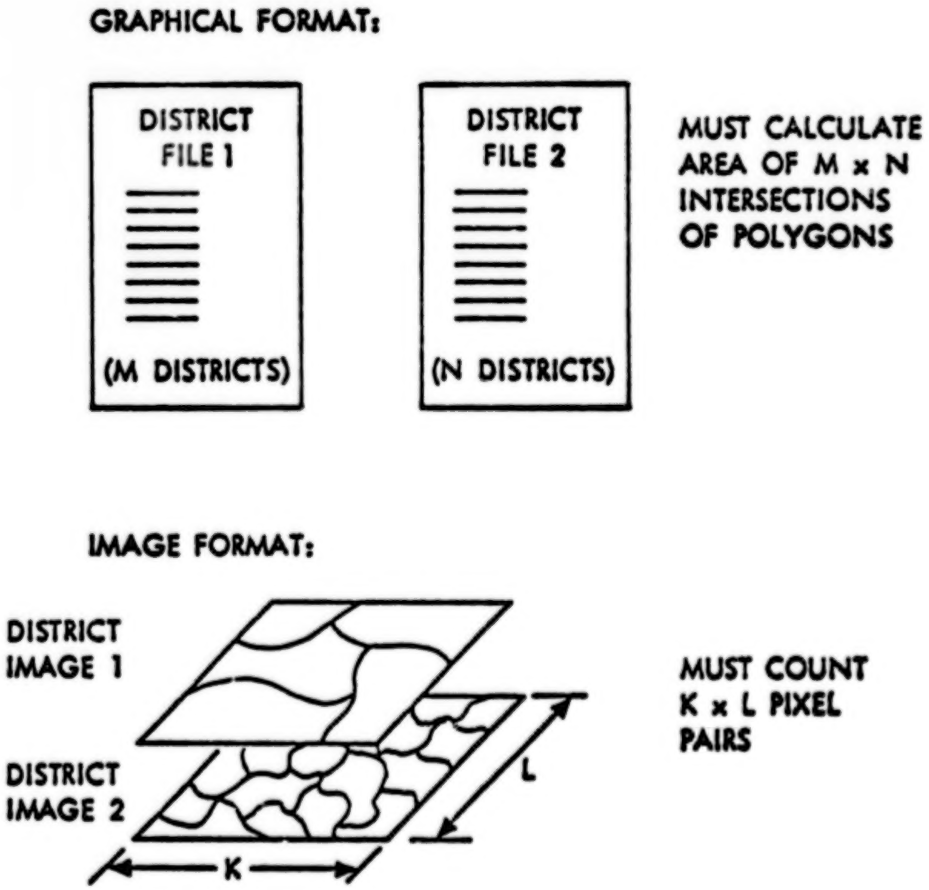

GRAPHICAL FORMAT:
DISTRICT FILE 1
(M DISTRICTS)
DISTRICT FILE 2
(N DISTRICTS)
MUST CALCULATE AREA OF M x N INTERSECTIONS OF POLYGONS
IMAGE FORMAT:
DISTRICT IMAGE 1
DISTRICT IMAGE 2
L
K
MUST COUNT K x L PIXEL PAIRS

Figure 8

always necessary to achieve the needed degree of accuracy. It is anticipated that even esoteric image processing operations, such as convolution smoothing will be useful for certain types of applications. The conclusion here is that any image-based information system must contain a powerful image processing subsystem.

Operationally, IBIS is configured the same as VICAR, and the two form an integral software system. The processing modules constitute a basic set of functions operating on the various datatypes to achieve the kinds of geobase manipulation suggested in the foregoing discussion. Figure 9 is a schematic layout of the central part of the IBIS system, emphasizing the interfaces between image, tabular, and geographical datatypes.

The first set of routines convert graphical (polygon) data files to digital image descriptions of regions or areas.

VTRACTI, SCRBGEN, VSCRBGEN - All three programs basically have the same function, convert polygon files described by x,y coordinates to a VICAR record format, but each uses a different input type:

VTRACTI - Census Tracts

SCRBGEN - Cards

VSCRBGEN - Tape

IBIS SCHEMATIC

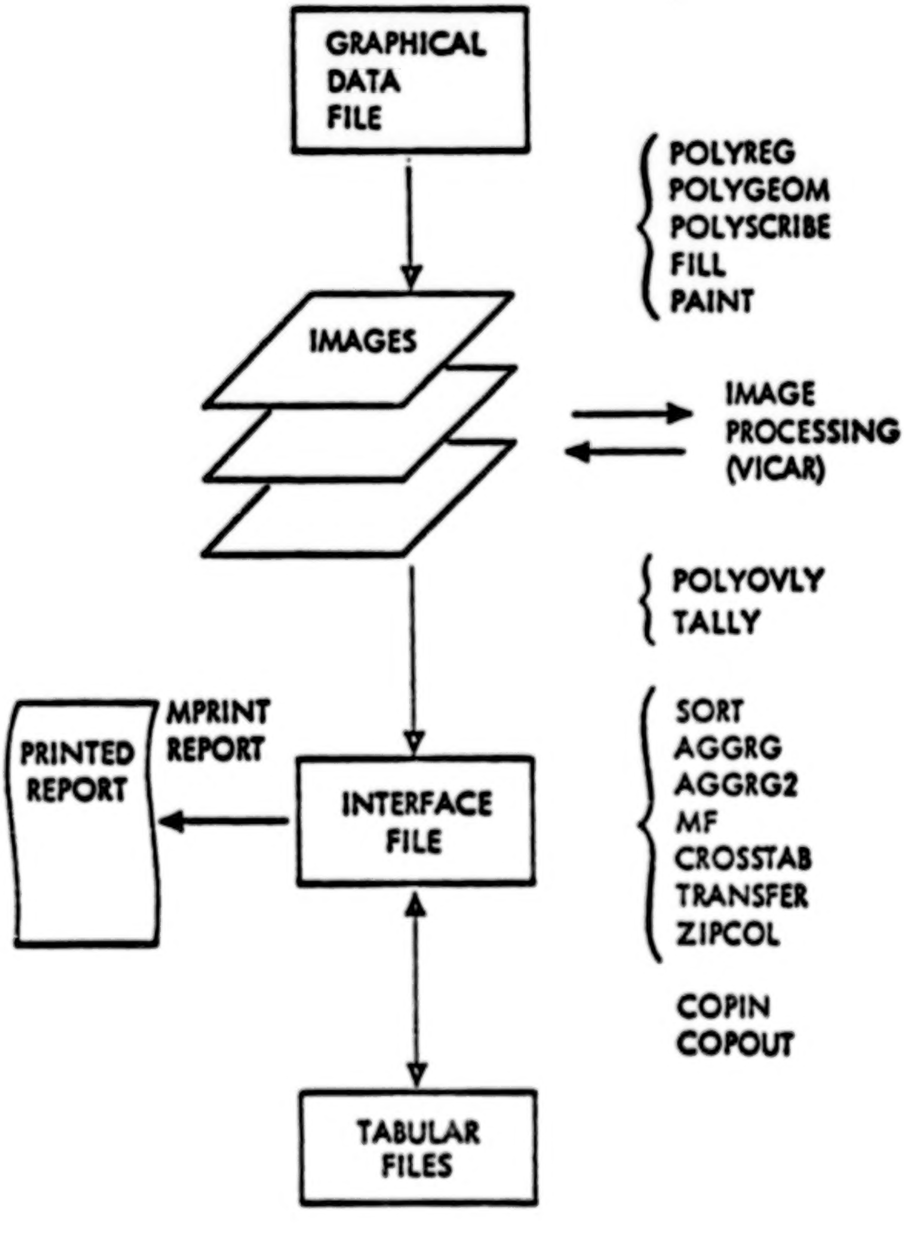

GRAPHICAL DATA FILE
POLYREG
POLYGEOM
POLYSCRIBE
FILL
PAINT
IMAGES
IMAGE PROCESSING (VICAR)
POLYOVLY
TALLY
MPRINT REPORT
PRINTED REPORT
INTERFACE FILE
SORT
AGGRG
AGGRG2
MF
CROSSTAB
TRANSFER
ZIPCOL
COPIN
COPOUT
TABULAR FILES

Figure 9

POLYREG - Performs rigid rotation and scaling of polygons prior to input into POLYSCRB.

POLYGEOM - Performs rubber sheet mapping on polygons prior to input into POLYSCRB.

POLYSCRB - Scribes lines into an image file, by setting the boundaries of polygons to a particular DN (gray scale) value. The routine was especially designed for the conversion of thousands of lines and has parameters for chaining lines and closure of polygons.

FILL - Fills holes, thickens lines and/or removes noise with variable thresholds and window sizes for enhancement of scribed polygons prior to PAINT.

PAINT - Converts an image with scribed polygons into a multi-color map where the DN corresponds to a map color. The routine will handle up to 30,000 polygons or regions.

Moving from top to bottom in Figure 9, the VICAR image processing routines are next. The VICAR system presently has over 100 routines for the manipulation of images of varying work length. Of special interest to modellers is the following routine:

F2 - Performs array arithmetic on a pair of images in byte or halfword format. The function to be applied is specified by a FORTRAN-like expression.

Polygon information extraction routines perform the overlay operation on two sets of polygons, the reference polygon created in PAINT and digital image data. Each pixel on the image file is matched with the corresponding pixel on the reference file and stored by pixel pairs. The following programs are used in the overlay process:

POLYOVLY - Produce a histogram (or pixel count) of registered images by DN values for single pixels or a joint histogram by DN pairs as generated in the overlay procedure. Since the problem of storage is critical to this process, the user has three optional storage methods specified in the parameters.

TALLY - Produces a histogram similar to POLYOVLY except that the DN values in one of the two images are summed.

The results of POLYOVLY and TALLY generate data files stored by column. The column organized file is called the interface file. This file serves as an interface between image and tabular data sets. The interface file is manipulated to produce a report by the following routines:

SORT - Sorts the interface file into ascending or descending order according to one or more columns.

AGGRG - Aggregates columns of numbers using a designated column as an index for summation in other columns.

AGGRG2 - Summarizes and collates columns of numbers to produce a single row for each control value in the column which is used as an index.

MF - Performs column arithmetic given an arithmetic expression in the parameter field which denotes columns such as:

"C5=C2/C3+100+SQRT(C2)".

CROSSTAB - Tabulates information referenced to one polygon districting to another polygon districting through the polygon overlay technique.

TRANSFER - Change vertically aligned columns of data as produced in POLYOVLY and used in previous routines to smaller vertical columns based upon data values (e.g., land use).

ZIPCOL - Substitutes column index values with user district names or numbers.

After processing by the above routines, the interface file is ready for report generation.

MPRINT - Prints out the interface file according to a relatively simple format.

REPORT - Prints out the interface file with user specified titles, column titles, paging, spacing, etc. Subtotaling on a given control column can be requested. There are numerous features for formatting and for printing alphabetic data.

To interface tabular files and also to give tape output as an alternative to report generation, the following routines are used.

COPIN - Copies columns of a tape file into columns of the interface file according to an index column in the interface file. The index must be present in the tape file. The files must be sorted according to the index and a merge is performed.

COPOUT - The reverse of COPIN. Columns are written from the interface file to the tape.[7]

Transferability. VICAR has been installed on an IBM 360/67 system at NASA-Ames and is currently being considered for installation on several state systems. Modular design, FORTRAN programming and good interfaces to commonly available hardware are factors that make VICAR/IBIS relatively transferable. On the other hand, the hardware requirements are substantial and to some extent specific to the system. Implementation of VICAR/IBIS certainly requires a serious, long-term commitment on the part of a computational facility for its support, maintenance, and adaptation to user needs.

The source code and limited system documentation for VICAR as configured for IBM 360/65-OS/MVT are available from COSMIC.[8] Another version of VICAR/IBIS designed for use in an interactive mode on minicomputer-based systems is currently under development at JPL.

Image Processing Systems at Ames Research Center

Ethel Bauer of NASA-Ames described the four systems available there for support of the Western Regional Applications Program: (1) the Electromagnetic Systems Laboratory IDIMS (Interactive Digital Image Manipulation System), (2) the ARPANET/EDITOR system, (3) JPL's VICAR software system, and (4) ERL's image processing software.

IDIMS is a "stand-alone" system based on software packages run on a dedicated HP 3000-Series II minicomputer, a COMTAL color display, and peripherals that include, in addition to disks and tape drives, an Autotrol digitizer and Tektronics X-Y display.

IDIMS is a general purpose image processing system with a large menu of functions, including routines for supervised and unsupervised clustering and maximum likelihood classification. It is convenient and effective for developing spectral classifications of Landsat data, using the interactive display to review raw data, identify and enter training sites, and obtain test classifications. The 512^2 screen area can be used to display this number of Landsat pixels, a smaller portion of an image can be enlarged to fill the screen, or a larger portion of an image can be displayed by subsampling. Three-band data can be displayed in false colors. Training site boundaries are entered by track ball. The X-Y display (with hardcopy) is used to produce spatial plots of cluster statistics.

The COMTAL is also useful for displaying the color-coded, classified data and district boundary sets (masks) digitized on the Autotrol for generation of tabular summaries. The GES-ERIS package is used to reference geographically a classified data set and to statistically merge Landsat-derived and other geographic data -- as required for a multistage sample/correlation analysis.

IDIMS is very limited in its capability for bulk classification because of the slow speed of the processor. Bulk jobs are off-loaded to a CDC 7600 mainframe computer at Ames for which a maximum likehood classifier has been developed.

Map output is produced by lineprinter or DICOMED color film recorder, devices which are also used with other Ames systems. Color photographs taken from the COMTAL screen are also a simple and effective product for presentation purposes.

IDIMS has been the principal system used for training at Ames and has supported many of the demonstration projects in the Pacific Northwest and other WRAP States.

ARPANET is the national computer network of the Advanced Research Projects Agency of the Department of Defense and includes many computer facilities accessed at terminal input points (TIPS) such as Ames. The ILLIAC-IV-TENEX computer system at Ames is a focal point of the network and provides unique computational power for certain functions such as scene registration, mosaicking and bulk classification.

EDITOR is a multipurpose Landsat classification program for use on ARPANET, developed by the University of Illinois Center for Advanced Computation (CAC). Further development and maintenance of EDITOR has recently passed from CAC To the Institute of Advanced Computation (IAC), which manages ILLIAC, and a new, user-oriented manual has been produced. Chief users of ARPANET/EDITOR have been the USDA Statistical Reporting Service, and the USGS Geography

Program research group stationed at Ames under the direction of Leonard Gaydos. The system has been used for the Puget Sound Urban Land Use Project and for other USGS-assisted work in Idaho, Alaska, and the San Francisco Bay Area.

EDITOR does not utilize a color display. However, it can be characterized as an interactive system. An on-line digitizer is the key to such operations as development of a calibration file for image-to-map reference, introduction of training sites and strata boundaries, and digitization of district boundaries for data summary. Transmission to and from the terminal is primarily conversational (instructions, commands, statistics), plus small amounts of data (map coordinates, classified Landsat data for small windows). The language is "friendly," incorporating a prompt system and an automatic hierarchy of statements.

Gaydos describes the process of interactive classification using EDITOR as "guided clustering," a combination of supervised and unsupervised routines, in stages, with evaluation and editing of cluster statistics at each stage. Scattergrams of raw data, spatial plots of cluster statistics, and test classificatins of small windows are feedback mechanisms used for evaluation. All this is received on the lineprinter terminal, except for cluster plots, which are drawn on the X-Y plotter which is also used to check digitization. The chief disadvantage of the lack of a display is in evaluating results for larger areas or for a whole study area. The analyst must wait for production of bulk lineprinter or DICOMED color-coded map output.

During the past year, Professors Larry Fox at Humboldt State University and Duane Shinn at the University of Washington have participated in demonstrations of ARPANET/EDITOR use from remote terminals linked to the Ames TIP by telephone line. Professor Shinn commented that this configuration proved workable for most operations, however noise in the phone line prevented on-line digitization of multi-part district map files.

Access to ARPANET remains a problem because of the lack of other available TIPS in the Western States, and the relatively high cost of regular phone or leased line connection. IAC support for widespread use of ARPANET/EDITOR is also an unresolved issue at this time.

The two other systems operating at Ames are the Jet Propulsion Laboratory VICAR and Earth Resources Laboratory software packages described earlier in this paper. The basic VICAR routines for image logging, geometric correction, and supervised classification are operated in batch mode on the Ames IBM 360/67 computer. Additional routines, including IBIS, will be added in the near future. VICAR-IBIS will be used at Ames for training and demonstrations, and as a test bed for assisting some WRAP states in transferring this software system to their own computer facilities. The basic ERL image processing software modules are also running, in batch mode only, on the SEL-32-55 computer at Ames, and are being evaluated for special capabilities that they can add to Ames' present complement of digital processing technology.

Questionnaire Assessing Digital Image Processing Capability

The questionnaire distributed to participants in the Computer Processing Workshop is an attachment to this paper. The questionnaire was intended to survey existing image processing capability at colleges and universities, i.e., functioning hardware/software systems, and also potential capability represented by system components such as computers, display devices, and other hardware. Current use of either type of capability was queried, as well as interest in acquiring NASA-developed software or in obtaining access to the ARPANET/EDITOR system.

Responses are summarized in Table 2. Within the WRAP states, there were 26 respondents representing 20 academic institutions. Eleven institutions indicated a functioning capability for digital image processing. This included 4 institutions in California (only one campus of the University of California was represented), and one institution each in Alaska, Arizona, Colorado, South Dakota, Utah, Oregon and Washington. An additional 3 institutions that did not indicate a functioning capability appear to have significant potential capability in terms of hardware, and indicated an interest in pursuing development. Fifteen institutions in the WRAP States indicated interest either in acquiring NASA-developed software or obtaining access to ARPANET.

TABLE 2

SUMMARY OF QUESTIONNAIRE RESPONSES
DIGITAL IMAGE PROCESSING CAPABILITY OF WESTERN STATES' ACADEMIC INSTITUTIONS

Institution (Alphabetical by State)	Division	Respondent(s)	Functioning Image Processing Capability?	Potential Capability (Hardware)	Use Emphasis*	Multi-Disciplinary?	Interested in NASA-developed software	ARPANET
Univ. of Alaska	Geophysical Inst.	John Miller	Yes	Significant	T,R,D	Yes	Yes	?
"	"	Paula Krebs	"	"	R	"	"	No
Univ. of Arizona	Arid Lands	R. Schowengerdt	Yes	Significant	T,R	Yes	Yes	Yes
"	Mining & Geol.	Charles Glass	"	"	T,R,D	"	"	-
U.C. Berkeley	Space Sci./For.	R. N. Colwell	Yes	Extensive	T,R,D	Yes	Yes	Yes
U.S.C	Image Processing	F. Sabins	Yes	Extensive	T,R	No	Yes	Yes
"	Geography	John McDonald	"	"	T,R,D	Yes	"	"
Cal St. Long Beach	Geol. Sci.	Bert Conrey	No	Significant	T,R,D	-	Yes	Yes
Cal St. Humboldt	Forestry	Lawrence Fox	Yes	Limited	T,D	No	Yes	Yes
Cal. Polytechnic	Agr. Eng.	Rollin Strohman	Yes	Significant	T,D	Yes	Yes	No
Sierra College	-	Vern Popp	No	-	-	-	-	Yes
Colorado State U.	Earth Resources	James A. Smith	Yes	Significant	T,R,D	Yes	Yes	Yes
USAF Academy	-	C. L. Smith	No	-	-	-	-	-
Univ. of Hawaii	Geography	E. Wingert	?	Significant	T,R	Yes	Yes	Yes
Treasure Valley Col	Agr.	Ken Knothe	No	-	T	Yes	-	-
Univ. of Nebraska	Cons. & Survey	Paul Seevers	Yes	Significant	R	Yes	Yes	Yes
U. Nevada Reno	School of Mines	J. Lintz	?	Significant	T,R,D	Yes	-	Yes
Oregon State U.	ERSAL	RJay Murray	Yes	Extensive	T,R,D	Yes	Yes-ERL	Yes
"	Forest Mgmt	David Pain	"	"	T,R	"	-	-
"	Geography	James Lahey	"	"	T,R	"	Yes-Topo	-
Central Ore. Com Col	Forestry	Richard Niederhof	No	-	T	No	-	-
Portland State U.	-	G. T. Benson	No	Some	-	-	-	-
S. Dakota State U	R.S. Inst.	Don Moore	Yes	Extensive	T,R,D	Yes	Yes	Yes
"	Plan Science	F. C. Westin	-	-	-	-	-	-
Univ. of Utah	Geography	Chung-Myun Lee	Yes	Significant	R	Yes	Yes	Yes
Univ. of Washington	Urban Planning	Duane Shinn	Yes	Significant	T,R,D	Yes	Yes	Yes
Washington State U.	Agr. & Soils	Bruce Fraizer	-	Significant	T,R	-	Yes-VICAR	Yes

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* T - Teaching
R - Research
D - Demonstration

References

1. Whitley, Sidney L., Low Cost Data Analysis Systems for Processing Multispectral Scanner Data, NASA Technical Report No. TR R-467, Washington: National Aeronautics and Space Administration, October 1976.

2. NASA Earth Resources Laboratory, Data Analysis Station Manual, Program Abstracts, Procedure 201, Slidell: Earth Resources Laboratory, June 6, 1978. The source codes and documentation for the ERL programs are available from COSMIC at the following address:

   COSMIC
   Computer Center
   112 Barrow Hall
   University of Georgia
   Athens, GA 30601
   Telephone: (404) 542-3265

3. For additional information regarding the ERL System, contact:

   Sidney L. Whitley, Chief
   Data Management Group
   Earth Resources Laboratory - NSTL
   1010 Gause Blvd.
   Slidell, LA 70458
   Telephone: (504) 255-6525

4. Seidman, J. B., VICAR Image Processing System, Guide to System Use, JPL Publication 77-37, May 1977.

5. Parts of this description of the VICAR software system are excerpted from a paper by William B. Green, Manager of the JPL Science Data Analysis Section, titled "Digital Techniques for Processing Landsat Imagery," prepared for presentation at the Third Jerusalem Conference on Information Technology, Jerusalem, Israel, August 6-9, 1978. The paper presents research conducted at the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under NAS 7-100.

6. This effort is described in a paper by Nevin A. Bryant, Anthony J. George, Jr., and Richard Hegdahl, titled "Tabular Data Base Construction and Analysis from Thematic Classified Landsat Imagery of Portland, Oregon," presented

at the 1977 Machine Processing of Remotely Sensed Data Symposium, Laboratory for Remote Sensing, Purdue University, Lafayette, Indiana, 1977. The paper presents research conducted at the Jet Propulsion Laboratory, sponsored by NASA under NAS 7-100.

7. Parts of this description of the IBIS system were excerpted from an unpublished paper by Nevin A. Bryant and Albert L. Zobrist titled "An Image Based Information System: Architecture for Correlating Satellite and Topological Data Bases." The paper presents research conducted at the Jet Propulsion Laboratory, sponsored by NASA under NAS 7-100.

8. Same address for COSMIC as in Reference #2.

Attachment

BRIEF ASSESSMENT OF DIGITAL IMAGE PROCESSING CAPABILITY

NAME__________________________ POSITION______________________

UNIVERSITY AND DEPARTMENT____

Describe University and/or Department hardware/software capability for Digital Image Processing of Landsat and other remote sensing data.

Please specify type of: Computer; Display; Output Devices; Software, etc.

Current use of capability (System/Facility)

(1) Teaching

(2) Research

(3) Demonstration Projects

(4) Other

Is System/Facility shared by several Departments? Specify

Are you interested in acquiring NASA developed software described at conference? If so, specify if possible.

Are you interested in potential access to the ARPANET for Image Processing?

Anticipated uses (1) Teaching

(2) Research

(3) Demonstrations

(4) Other

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THE REDUCTION OF REMOTE SENSING DATA BY VISUAL MEANS

by

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Associate Director, Space Sciences Laboratory
University of California;

Charles E. Poulton
Training Officer, Western Region Applications Program
NASA Ames Research Center;

and

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Oregon State University

INTRODUCTION

The purpose of this paper is to define the problems, state the objectives, and address the issues that are most likely to be of concern to educators when they are called upon to teach courses involving the reduction (interpretation) of remote sensing data by visual means. The paper will consider the following topics in sequence: (1) the information requirements of those who use remote sensing-derived information; (2) some general educational concepts that are involved in teaching students how to generate the desired information from a visual analysis of remote sensing data; (3) some principles and techniques that are specific to the photo interpretation process; (4) concepts involved in the making of photo measurements, as dictated by the geometry of remote sensing imagery; (5) the nature and use of various kinds of mapping, plotting and photo interpretation equipment; and (6) some special considerations with respect to "convergence of evidence" and other principles involved in the interpretation of photographs. The paper will conclude with an Appendix dealing with a recommended procedure for determining the usefulness of any given type of aerial or space photography in relation to the inventory of natural resources.

The fact that this conference has been called suggests that there is some degree of apprehension and possibly a real basis for the assumption that efforts in the field of remote sensing education, and thus in technology transfer and application, are not keeping pace with advancements in the science and art. Granted that this may be a valid assumption, the primary problem and challenge which we face is to devise and implement ways and means of catching up and of keeping remote sensing education and training more nearly abreast of the rapidly advancing science and technology. Our goal in this presentation is to stimulate you to think with us and contribute ideas on how this might be achieved in the area of visual analysis of remote sensing imagery.

In the instructions that were given to us by the conveners of this Conference of Remote Sensing Educators we were advised that we should, when addressing each of the above-listed topics, suggest the methods and strategies which an educator might best use in teaching it. Consequently, the material contained in this paper consists of an admixture of two elements: (a) basic information relative to each of the above-listed topics, and (b) recommendations on how that topic might best be presented by an instructor.

Many of the factors that relate to the reduction of remote sensing data by visual means have been dealt with by other participants in this conference. These include considerations with respect to (1) equipment and techniques used in the acquisition of remote sensing data; (2) criteria for use in selecting image analysts; (3) curricula for use in training them; and (4) specific textbooks, syllabi, multi-media presentations, and other aids for teaching such curricula. In the interest of avoiding duplication, we will include material in the above-listed categories only as necessary to provide continuity to the general discussion and relate to the specific examples that are about to be presented.

INFORMATION REQUIREMENTS OF THE USERS

At the outset, any instructor seeking to teach the subject of "Remote Sensing Data Reduction by Visual Means" should encourage student consideration as to the information requirements of the primary users of the resulting products. Even a cursory examination of this matter will reveal that virtually everyone is a "potential user", to one degree or another, of such information. Therefore, the instructor would be well advised to be selective and propose that this phase of the instruction be centered around some important and highly representative category of users. It would be ideal if he could select for consideration some category of users who (1) would be among those who would have the greatest use for remote sensing data on a continuing basis, and (2) would be sufficiently representative of the entire world-wide "user community" that principles of application could be clearly identified and stated, so inferences could be drawn from this discussion as to how others also might use remote sensing data. Perhaps the category of users that might best satisfy these two criteria is the one composed of individuals who are directly concerned with the inventory and management of the Earth's natural resources. In focusing on this category of users the instructor should briefly but concisely indicate why such scientists have a strong and continuing interest in remote sensing-derived information.

Given this central focus on managers of the Earth's natural resources, the instructor, we believe, should broaden his conceptual coverage beyond the renewable natural resource fields of forestry, range, agriculture, watershed, wildlife and recreation to bring into proper relationship two other elements in rational management of the Earth's resources--namely, nonrenewable resources, the exploitation of which is having a progressively greater impact on renewable resource management and secondly, the very complicated and politically sensitive area of land use. Land-use planning is one of the most rapidly growing areas of demand for information which can be met by a well-designed remote sensing approach. The requirements in these areas should be brought into perspective along with renewable resources even though we recognize that remote sensing application in geology and in land-use planning can and must eventually involve studies in depth and in their own right. When we fail to put the remote sensing and information needs for land-use planning and for certain kinds of nonrenewable, resource exploitation in the ecological context of an integrated inventory and analysis of the ecosystems comprising a specified geographic segment of the biosphere, we often foster a superficial approach to the evaluation of alternatives in the land-use decision process. Thus, it is extremely important to make clear to the students of remote sensing, the integrated ecosystems context within which he must work regardless of his professional specialty in the earth sciences.

At this point the instructor might emphasize that no complex rationale is required in order to relate remote sensing of the Earth's surface to the wise management of such earth resources as timber, forage, soils, water, minerals, agricultural crops, livestock, fish and wildlife, and to land-use. In fact, he might briefly but effectively dispose of this matter by expressing the rationale in a simple, five-part statement somewhat as follows:

1. Whether viewed on a local, regional, national, or global basis, the human demand for most kinds of earth resources is rapidly increasing at the very time when the supply of many of them is rapidly dwindling and the quality of others is rapidly deteriorating.

2. This situation makes it imperative that the alternatives and consequences in resource and land allocation for economic production, expansion and development, and for esthetic, education and scientific values be most carefully considered from an adequate information base.

3. Given rational, informed decisions on resource and land allocation, the situation of intense competition and high demand for certain kinds of resources calls for the wisest possible management of each of these resources in an effectively integrated, often multiple use, context.

4. Wise management is dependent upon informed, rational decisions. These are greatly facilitated if timely, accurate inventories are periodically made available to the resource manager, so that he will know at all times the amount and condition of each kind of resource that is present in each portion of the area that he seeks to manage.

5. Almost invariably such inventories can best be made by the acquisition and reduction of remote sensing data.

The usefulness to the resource manager of accurate, periodically acquired information about the status of the "resource complex" within the area for which he has management responsibility is most clearly seen by students when the instructor invites them to consider that the wise management of earth resources usually entails a four-step process: inventory, analysis, implementation, and monitoring as described below.

In the inventory step a determination is made as to the amount, quality and condition of each type of earth resource that is present in each portion of the area to be managed. In the analysis step, certain management decisions are made with respect to these resources. This is accomplished for each portion of the area by considering, (a) the nature and condition of its resources as previously established in the inventory step, and (b) both the "cost-effectiveness" and the "biological effectiveness" of each management alternative that might feasibly by exercised with respect to these resources. In the implementation step, the resource manager carries out each rational decision that has been made in the analysis step (e.g., the decision to apply the appropriate fertilizer in certain mineral-deficient parts of an agricultural area, or to cut only the over-mature trees in a certain portion of the forest area, or to practice "deferred rotation grazing" in certain parts of a range-land area, or to invest in certain development or rehabilitation projects). The resource manager, especially when dealing with such renewable natural resources as agricultural crops, timber, and forage is likely to find that these resources are highly dynamic rather than static and that he therefore needs to obtain a new inventory periodically--a process known as "monitoring"--as a means of refining the management program. It is achieved by recycling through the inventory and analysis steps with a particular emphasis on assessing the effectiveness of management actions.

At this point the instructor is likely to find it helpful to invite classroom discussion of either Table 1 or some suitable modification of it. In Table 1 we have listed the kinds of information sought (and hopefully obtainable through remote sensing data reduction) by workers in various disciplines that entail the inventory and management of Earth's natural resources. It will be noted there that we have listed, under each discipline, both the basic and applied information sought by workers in that discipline. This two-way subdivision is of considerable importance in relation to our defining the objective of data reduction by visual means. Therefore, if the instructor elects to use, and build upon, this subdivision he may wish to advance the

TABLE 1

BASIC AND APPLIED INFORMATION SOUGHT THROUGH REMOTE SENSING BY WORKERS IN VARIOUS DISCIPLINES

I. FORESTERS, PASTORALISTS, AND AGRICULTURALISTS
- A. BASIC
  1. Amount and distribution of the "biomass"
  2. Nature, extent, and function of important "ecosystems"
  3. Amount and nature of energy exchange phenomena
- B. APPLIED
  1. The species composition of vegetation in each area studied
  2. Vigor of the vegetation
  3. Where vegetation lacks vigor, the causal agent
  4. Probable yield per unit area and total yield in each vegetation type and vigor class
  5. Information similar to the above on dynamics of livestock, wildlife and fish populations
  6. Changes resulting from past practices

II. GEOLOGISTS
- A. BASIC
  1. Worldwide distribution of geomorphic features
  2. Energy exchanges associated with earthquakes and volcanic eruptions
  3. The nature of geomorphic and mineralization processes
- B. APPLIED
  1. Location of certain or probable mineral deposits
  2. Location of certain or probable petroleum deposits
  3. Location of areas in which mineral, and petroleum and ground water deposits of economic importance probably are lacking

III. OCEANOGRAPHERS
- A. BASIC
  1. Diurnal and seasonal variations in sea surface temperatures and subsurface temperatures
  2. Vertical and horizontal movements of ocean currents and individual waves
  3. Global, regional and subregional shoreline locations, characteristics and the changes in these characteristics with time
  4. Diurnal and seasonal movements of fish, algae and other marine organisms
- B. APPLIED
  1. The exact location, at a given time, of ships, icebergs, tsunamis, storms, schools of fish and concentrations of kelp
  2. The location of ocean beaches suitable for recreational development
  3. The rate of spread of water-pollutants and the kind and severity of damage caused by them
  4. Health/vigor of fish and mammal populations
  5. The formation of ocean storms and their movement to land areas.

IV. METEOROLOGISTS
- A. BASIC
  1. Diurnal and seasonal variations in cloud cover, wind velocity and air temperature and humidity in relation to topography and geographic locality
  2. Accurate statistical data on the points of origin of storms, the paths followed by them, their intensities, and their periods of duration
- B. APPLIED
  1. Early warning that a specific storm is developing
  2. Accurate tracking of the storm's course
  3. Accurate periodic data on air temperatures, humidity, and wind velocity
  4. Accurate quantitative data on the response of the atmosphere to weather-modification efforts
  5. Selection and assessment of precipitation and growing conditions in remote areas

V. HYDROLOGISTS
- A. BASIC
  1. Quantitative data on factors involved in the hydrologic cycle (vegetation, snow cover, evaporation, transpiration, and energy balance)
  2. Quantitative data on factors governing climate (weather patterns, diurnal and seasonal cycles in weather-related phenomena)
- B. APPLIED
  1. The location of developable aquifers and target areas for ground water exploration
  2. The location of suitable sites for impounding water
  3. The location of suitable routes for water transport
  4. The moisture content of soil and vegetation
  5. Systems of enhancing ground water recharge

VI. GEOGRAPHERS
- A. BASIC
  1. Global, regional, subregional, and local land use patterns
  2. The nature and extent of changes in vegetation, animal populations, weather, and human settlement throughout the world
- B. APPLIED
  1. The exact location, at any given time, of facilities for transportation and communication
  2. The interplay of climate, topography, vegetation, animal life and human inhabitants in specific areas
  3. The levels of economic activity and the purchasing habits of inhabitants in specific areas
  4. Geographic distribution and dynamics of socio-economic and political factors influencing the production and use of earth resources
  5. Land cover and characteristics related to land-use potential

following brief rationale for it: Basic research by definition seeks to understand the fundamentals on which a particular science rests; the types of data derived from basic research are therefore called "basic data" and, when analyzed, lead to the types of basic information listed in Table 1. On the other hand, applied research seeks to solve specific problems in an applied or practical manner. The types of data derived from applied research (and subsequently from operational systems and procedures based on such research) are therefore termed "applied data" and, when analyzed, lead to the types of applied information listed in Table 1.

Before leaving this matter the instructor may wish to illustrate the validity of the consequent categorization of informational requirements that has been set forth in Table 1. For example we have indicated there that foresters, pastoralists, and agriculturists wish to acquire basic information on "the nature and distribution of the earth's biomass"; on "the amount and nature of energy exchange phenomena" which involve vegetation, and on the functioning of the ecosystems of which they each are a part. University scientists in the disciplines of agriculture, forestry, and range, and certain other scientists as well are, indeed, justifiably interested in such basic information, and in its long-term significance. This basic information may even be of some small interest to the farmer, pastoralist, or forester in his capacity as a citizen of the world. However, he finds little in this kind of information that tells him how better to grow timber, livestock, or agricultural crops on the parcel of land for which he has management responsibility, nor even whether there is likely to be an overproduction or an underproduction of the type of agricultural, range, or forest product which he is in the business of producing. Instead he needs information of the "applied" type as to the vigor, for example, of the vegetation in each part of the forest, rangeland, or farm area which he is attempting to manage. Furthermore, in those places where the vegetation is suffering from a vigor loss he needs to know the identity of the causal organism or agent so that he can take the necessary remedial action. All of the above considerations are reflected in Table 1 under the heading "Foresters, Pastoralists, and Agriculturalists".

The remaining portions of Table 1 give distinctions between the basic and applied informational needs of other potential users of modern remote sensing technology, including geologists, hydrologists, geographers, oceanographers, and meteorologists.

In considering the informational requirements of scientists in any of the disciplines listed in Table 1, the instructor most likely will need to provide his class with a level of detail greater than that given in the brief listing that is contained in that table. Realization of this fact has prompted us to prepare, by way of example, a second table which pertains specifically to the informational requirements of those who are concerned with the management of land and vegetation resources. Table 2 treats these categories of vegetation and the general land category for which information is sought, viz., agricultural crops, timber stands, rangeland vegetation, and land-use. Starting with the lefthand column of that table we see that, by and large, the users of agricultural crop data need only six categories of information, viz., crop type, crop vigor, crop-damaging agents, crop yield per acre by type, total crop acreage by type, and total yield (more properly called total "production"). Proceeding to columns two and three in Table 2 we note that essentially these same six categories of information likewise are

TABLE 2

USER REQUIREMENTS FOR VEGETATION AND LAND RESOURCE DATA

Type of Information Desired

For Agricultural Crops	For Timber Stands	For Rangeland	For Land Use Decisions
Type of Agricultural System and Crop Type (species and variety)	Timber Type (Species composition)	Vegetation Type (Species composition)	Land Uses and Covertypes
Present crop vigor and state of maturity.	Present tree and stand vigor by species and size class.	Seasonal forage development, vegetation cover or density, condition and "Range Readiness" (for grazing by domestic or wild animals).	Present land use patterns, infrastructure and interrelationships; covertypes giving clues to kind and quality of use on the "natural, undeveloped" landscape.
Prevalence of crop-damaging agents by type.	Prevalence of tree-damaging agents by type.	Prevalence of forage-damaging agents (weeds, insects, rodents, diseases, abnormal growing conditions, etc.) by type.	Land use conflicts and potential conflicts; land-use needs under present and alternative economic growth policies.
Prediction of time of maturity and eventual crop yield per acre by crop type and vigor class.	Present timber volume by species capacity and merchantability classes per acre.	Present forage production and apparent trends in probable future productive capacity per acre by vegetation type and range condition class.	Land resource availability, lands (by present use classes and covertypes) with multiple use potential; for each land use and covertype area, determining capability for each potential use.
Total acreage within each crop type and vigor class.	Total acreage within each stand type and vigor class.	Acreage within each vegetation type and condition class.	Acreages by land use and covertype classes.
Total present yield by crop type.	Total present and probable future yield by species and size class; alternative and secondary values of the area by timber type.	Total present and probable future animal carrying capacity (domestic and wild) and alternative or secondary values of the area by vegetation type.	Human carrying capacity of the land under present and alternative economic growth policies.

the ones sought by the managers of timber lands, and rangelands, respectively. It is further noted that there is a very strong parallel between the kinds of information required by vegetation managers and land-use planners. They fall into the same general categories of basic inventory, negative production or decision influences, quality or productivity, acreage and finally carrying capacity.

Referring to Table 2, with the present population pressure on vegetation resources and the land, the three categories of vegetational resource managers shown are inextricably tied to the process of land-use planning and decision making because of the ever growing tendency of urban and industrially oriented man to usurp the best of the agricultural, rangeland and timber land for these other "higher economic uses." Thus, it is important to put the land-use decision process in proper perspective whenever one discusses information needs and processes in vegetation resource management. The land-use decision tends always to take place in a highly political atmosphere, often without regard to biological facts, future needs and pressures and the wisdom of long-term economics. The only hope for improving this situation lies in providing a better quantitative basis for the land-use decision process and a good understanding of the alternatives, potentials, and consequences of land-use change in agricultural, forested and rangeland areas. Thus, while the land-use decision process requires some unique kinds of information as indicated in column 4, Table 2, it also requires an intimate awareness of the factors in each of the remaining three columns according to dominant vegetational resource.

Next the instructor might raise the question dealt with in Table 3, viz., "how quickly and how frequently do the users need the information?". Obviously this matter will be of great relevance when consideration is given, a short time

TABLE 3

USER REQUIREMENTS FOR VEGETATION AND LAND RESOURCE DATA

Frequency With Which the Information is Needed (Examples Only)

To Convert This Table to "Rapidity With Which Information is Needed", Use "Half-Life Concept" (See Text)

For Agricultural Crops	For Timber Stands	For Rangeland	For Land-Use Decisions
10-20 mins. - Observe the advancing waterline in croplands during disastrous floods. Observe the start of locust flights in agricultural areas.	10-20 mins. - Detect the start of forest fires during periods when there is a high "Fire Danger Rating".	10-20 mins. - Detect the start of rangeland and brushfield fires during periods when there is a high "Fire Danger Rating".	10-20 mins.- Not applicable.
10-20 hrs. - Map perimeter of on-going floods and locust flights. Monitor the Wheat Belt for outbreaks of Black Stem Rust due to spore showers.	10-20 hrs.- Map perimeter of on-going forest fires.	10-20 hrs.- Map perimeter of on-going rangeland and brushfield fires.	10-20 hrs.- Not applicable.
10-20 days - Map progress of crops as an aid to crop identification using "crop calendars" and to estimating date to begin harvesting operations.	10-20 days - Detect start of insect outbreaks in timber stands.	10-20 days - Update information on "Range Readiness" for grazing, on forest utilization in critical periods and also information on times of flowering and pollen production in relation to the bee industry and to hay fever problems.	10-20 days - Monitoring compliance with certain codes and construction itself in critical areas of land-use change or during peak construction periods.
10-20 mos.- Facilitate annual inspection of crop rotation and of compliance with federal requirements for benefit payments.	10-20 mos.- Facilitate annual inspection of firebreaks.	10-20 mos.- Facilitate annual inspection of firebreaks, range production and range conditions.	10-20 mos.- Monitoring development and land-use change in critical areas for enforcement of codes and keeping valuations equitable and up to date.
10-20 yrs.- Observe growth and mortality rates in orchards.	10-20 yrs.- Observe growth and mortality rates in timber stands.	10-20 yrs. - Observe signs of range improvement or deterioration, study the spread of noxious or poisonous weeds. Observe changes in "Edge Effect" of brushfields that affect suitability as wildlife habitat.	10-20 yrs.- Reassess situation as per Table 2, Col. 4 to fine-tune long term land-use plan and reevaluate policies. Provide improved data for prediction models and trend analysis. Revise or set long-term economic development goals.
20-100 yrs. - Observe shifting cultivation patterns.	20-100 yrs.- Observe plant succession trends in the forest.	20-100 yrs.- Observe major plant succession trends on rangelands and brushfields.	20-100 yrs.- Document long-term changes in land-use and monitor attainment of long-term development goals.

later in the course, to man's ability to derive this information through the reduction of remote sensing data by visual means. It will be noted in Table 3 that the same headings as appeared in Table 2 have been used for the four vertical columns. At the risk of some oversimplification, this table lists six time intervals that are indicative of the frequency with which various kinds of information about vegetation and land resources are needed (10-20 minutes; 10-20 hours; 10-20 days; 10-20 months; 10-20 years; and 20-100 years).

In inviting students to consider relationships between the frequency with which Earth resource data should be collected and the rapidity with which the collected data should be processed, the instructor might wish to employ the term "half-life" in much the same way as it has been employed by radiologists and atomic physicists. The shorter the isotope's half-life, the more quickly a scientist must work with it once a supply has been issued to him. One half-life after he has acquired the material only half of the original amount is still useful; two half-lives after acquisition only one quarter of the original amount is useful, etc.

By coincidence or otherwise, this half-life concept seems to apply remarkably well to nearly every item listed in Table 3. Specifically, if the desired frequency of acquisition of any given type of information, as listed in that table, is divided by two, a figure is obtained indicating the maximum time after data acquisition by which that particular item of information should have been extracted from the data and put to use. It is true that some value will accrue even if that item of information does not become known to the resource manager until somewhat later. But the rate at which the value of the information "decays" is in remarkably close conformity to the half-life concept.

Some students, on being exposed to this concept, will very likely regard it as an oversimplification, fraught with errors and inconsistencies. If so, a thoughtful and stimulating discussion should ensue which, according to some experts on the strategy of teaching, represents the educational process at its best.

As previously indicated, there is a high degree of diversity in the user requirement for information on the vegetation and land resources of an area. Consequently, the three tables which have just been presented probably would be considered in need of major modification before they would accurately portray the informational needs of any particular user. For example, many users think almost entirely in terms of protecting the vegetation resource from damaging agents, occasionally even through the extreme of non-use, and thus would view the problem somewhat more narrowly than we have viewed it here. On the other hand, there are those who think of the vegetation resource as one of the many items which comprise the total "resource complex" in a given land area which they must manage as a nonrenewable resource but with a multiple-use intent of conversion to economic goods. Almost certainly they would view the problem more broadly than we have in these tables, and in so doing would point to the importance of such non-vegetational components as landforms, soils, water, minerals, wildlife, and recreational potential. Therefore, as part of the "strategy" for teaching this part of the course, the instructor might first point out these narrower and broader ways of viewing the matter and encourage student reaction.

Finally, as a class exercise, the attempt might be made to construct, for non-vegetation resources, tables similar to those that have been presented here for vegetation resources. It is probable that, upon completion of that effort, adequate attention would have been given to the information requirements of those who are the potential users of information that can be obtained through the visual analysis of remote sensing data. Consequently, in the light of that knowledge, the instruction could then be directed (along the lines indicated in the remainder of this paper) to the principles, equipment, and techniques used in deriving such information through the visual analysis of remote sensing data.

EDUCATIONAL CONCEPTS THAT ARE INVOLVED IN TEACHING STUDENTS HOW TO VISUALLY GENERATE INFORMATION FROM AN ANALYSIS OF REMOTE SENSING DATA

Certain of these concepts are of such a general nature that they need to be considered in the teaching of virtually any subject matter, whether it deals with remote sensing or not. Recognition of this fact has led various thoughtful educators to prepare "rating sheets" by means of which students can evaluate the effectiveness with which any given course has been presented to them. Such rating sheets usually consist of a series of questions, each of which deals with some important factor in relation to the effectiveness with which the course has been taught. Perhaps there is no better way for us to succinctly cover these general educational concepts than through a listing, as in Table 4, of certain of the questions which are most commonly found in such rating sheets.

Every educator owes it to himself, and also owes it to his students, to be familiar with questions of the type appearing in Table 4 and with the educational concepts on which those questions rest. So basic are they to success in teaching that it would be presumptuous of us to include them here, were it not for one deplorable fact: Most educators at the college or university level (i.e., at the level represented by the attendees at this Conference of Remote Sensing Educators) have never received instruction in how to teach effectively. For some reason the tradition has developed over the years that, if an individual possesses an advanced degree in some subject matter area from a respectable institution of higher learning, he is well equipped to teach that subject to college or university level students even though he has never taken courses in the field of Education--i.e., in how to teach. The importance of such courses is acknowledged elsewhere, however; for example, unless he has taken such courses, he probably would not be

TABLE 4 - SOME TYPICAL QUESTIONS USED IN EVALUATING REMOTE SENSING INSTRUCTORS AND COURSES

I. The Instructor

A. Is he knowledgeable about material covered in the course?

B. Does he take care to differentiate between established facts and personal opinions?

C. Does he present the material clearly, concisely and in a well organized fashion?

D. Does he stimulate class discussion and respond courteously and forthrightly to questions?

E. Are his examinations clearly worded, adequately comprehensive, of reasonable length and frequency, and fairly graded?

F. Does he show enthusiasm for the subject matter and instill this enthusiasm in the students?

G. Is he interested in the students as human beings even to the point of learning their first names and making himself available for personal conferences?

II. The Course

A. Is there a required text that is used effectively?

B. Are representative photographs and other forms of imagery incorporated into the course and used as the basis for laboratory or workshop problem sets?

C. Is the laboratory working space suitably furnished and lighted?

D. Is adequate photo interpretation equipment available and is it effectively used in "hands on" training exercises?

E. After problem sets have been completed is an accurate "school solution" presented against which a student can gauge his performance?

F. Is the course made suitably broad through the use of additional image examples in the form of slides, motion pictures, demonstration posters, etc.?

G. Is effective use made of field trips and occasional guest lecturers as opportunity permits?

H. Upon completion of the course is each student given the opportunity to give a frank, discreet, constructive appraisal of it?

considered adequately trained to teach students in any of the elementary or high school grades. Furthermore, despite lip service given to the concept that the promotability of a professor depends primarily upon his demonstrated teaching ability, it has been our experience that any professor who, over the years, has made known the results of his research efforts by publishing a sufficient number of articles in "referee journals" has axiomatically demonstrated his worthiness for promotion. This seems to be so even though it is acknowledged that such activity usually provides little or no evidence of his ability to fulfill his primary responsibility in teaching, rather than in conducting research and writing scientific papers about it.

While we readily acknowledge that there are commendable exceptions to the generalizations that have just been given, and that one can learn the principles and procedures for effective teaching without voluminous and often redundant course work in the subject, we consider it very probable that many an educator attending this conference will find it quite revealing to evaluate his own teaching ability in relation to the questions contained in Table 4. Our apologies go to those who do not find it so--and our assurances, also, that we will not further belabor this topic.

Corollary with the question of qualifications of instructors, we should address as one of the general educational concepts the question of minimum educational level for a trainee about to become involved in directed study of remote sensing. Our collective view on this subject can be summarized quite succinctly. We believe that the visual interpretation of remote sensing imagery is very strongly dependent on the understanding and capability of the interpreter in the disciplinary subject matter area for which he is attempting to extract information; thus, we believe the most effective education and training in remote sensing will take place after the students have reached the equivalent of upper division status in a resource related discipline, and that remote sensing technology should be presented as one of the professional tools of that discipline rather than an isolated science and art in its own right. Even though we recognize that remote sensing technology may some day advance to separate degree status in some universities, it will be a hollow science and art without very strong and highly capable input of the type coming only from understanding of the disciplines to be served.

In summary, then, we believe that mention of these two points — teaching capability and knowledge of a resource discipline — is both necessary and sufficient as we seek to treat appropriately one of the topics which we were asked to address, viz., "What are the general educational concepts that are involved in teaching students how to generate information through the visual analysis of remote sensing data?"

There are certain specific educational concepts, however, that we and our associates have found to be quite important for successfully teaching the course material that is dealt with in this paper. Several of these concepts will be dealt with in the remainder of the present section, while others will be presented in connection with some of the related topics which follow:

1. It is of paramount importance to select a single test site or instructional area where various kinds of imagery can be acquired during different seasons, at different scales, and where a wealth of ground information can be accumulated and summarized as a basis for the instructional program. Such areas should be selected because of their general suitability for teaching the principles and concepts. It is not so important that they represent any particular kind of resource area; but generally speaking, to the extent that

they do represent multiple land-use possibilities and varying resource conditions in a relatively compact area, easily accessible by road, the laboratory area approaches the ideal. One such example is the Bucks Lake test area developed by the University of California, Berkeley, where the following kinds of remote sensing data and background information have, for example, been accumulated: (1) Conventional large scale (1/20,000) aerial photos in color, color infrared and four black-and-white film/filter combinations; (2) High flight photography, scale 1/130,000, of these same types; (3) Landsat multiband and color composite imagery as obtained from both the MSS system and the RBV system; (4) Day and night thermal infrared imagery obtained in the 8-14 micron band; and (5) Side-looking airborne radar (SLAR) imagery obtained in the 1-3 centimeter band.

The selection and concentration on a single test area also enables one to develop some highly reliable problem sets with expertly derived answers or solutions to be used as a check against the performance of the students. When all these advantages are considered, one can rarely justify spreading instructional and laboratory fieldwork over a diverse set of geographically separated locations. The important point is that the principles and procedures be learned well. If this is achieved, capable students can easily adapt to the requirements of their own discipline should it not have been included in the sample laboratory problem.

2. One of the most important educational concepts in remote sensing instruction is derived from the very nature of the subject itself. It is admirably suited to teaching through hands-on problem sets, laboratory and by field exercises which drive home the principles through direct student involvement. In the main, the principles of visual interpretation of remote

sensing imagery are well covered in textbooks and manuals. The essentials can easily be summarized from these standard references in the design and outlining of laboratory problems and procedures. Thus, visual interpretation is not a subject in which we would generally recommend high dependence on the lecture approach. It is our feeling that the instructor should always strive to minimize formal lecture. He should emphasize problem sets, laboratory exercises and the discussion thereof as the primary teaching mechanism.

The subject is also well suited to problem and laboratory exercises that end in a comparison of results. Students should be encouraged to compare and discuss both what they did and how they arrived at their various decisions. Where laboratory problems are built around a single test area as suggested above, it is also possible to compare student results with a very adequate standard which is a composite of the instructor's ability, the cumulative experience of preceding student groups and a strong body of ground knowledge and verification. The two major benefits of this approach to instruction are the discussion that it generates and the reinforcement of learning that is achieved through the group dynamics approach.

3. It is also important to give students an understanding of accuracy limits and factors contributing thereto. This can be done by involving them in laboratory tests of interpretation accuracy. Such tests have the practical value of enabling selections of the most capable among the test group for operations projects and selections among imagery types for specified purposes. Following are some simple but well-tested and workable procedures for making and presenting the results of such tests.

Accuracy of interpretation is conventionally documented by having a number of interpreters, after an appropriately intensive training period, identify a large number of areas representing each image and information class and then displaying the results in omission/commission error tables comparing student answers with highly accurate "ground truth."

It may be desirable to evaluate different kinds of photography or imagery to determine the ones best suited to accurate discrimination of essential information classes. When the same task as recommended in the previous paragraph is performed by several interpreters on different kinds of imagery, the data can provide a basis for selecting among the most appropriate imagery types on the basis of interpretation accuracy. By similarly using about 5 to 10 well-trained interpreters working under identical and strict mapping guidelines with the same legend system another approach may be used. Each interpreter is asked to map the same geographic area on each of the imagery types. The results can then be compared to provide a basis for selecting among the most appropriate imagery types or for planning how to use each of the selected types of imagery in different parts of the inventory project. A more detailed discussion and illustration of these considerations will be found in Appendix A.

By calculating the differences in interpretation accuracy among all possible comparisons of imagery types, a matrix table of significant differences can be helpful in making the best compromises when selecting the imaging system to be used.

4. It is highly desirable to include, in the laboratory phase of a remote sensing course or workshop, at least one instructional exercise that employs some technique of projecting both members of a stereoscopic pair of photos onto a screen in such a way as to permit the instructor and all members of the class simultaneously to view an area of interest three-dimensionally. This can be accomplished, for example, in either black-and-white or color,

through the simultaneous use of two projectors equipped with cross-polarized filters and projecting the images onto a smooth-surfaced (silvered) screen rather than onto the conventional "beaded" screen. When this technique is used, each person viewing the screen, of course, wears a pair of spectacles the lenses of which are mounted in cross-polarized positions such that only the left of the two projected images is seen with the left eye, while only the right image is seen with the right eye. Such three-dimensional viewing greatly facilitates the efforts of the instructor to point out the natural resource attributes of an area and to consider, with the students, various resource management alternatives.

5. Finally, it is important for the instructor, throughout the course, to emphasize that most of the image analysis done by humans (especially that leading to the production of maps of an area's natural resources) entails two distinct steps: (1) delineation, and (2) identification. In delineation one merely defines (delineates or marks out) the homogeneous image areas in the scene according to specified mapping criteria and guidelines. In the process one may make tentative decisions as to which image areas are analogous. While the experienced interpreter may follow each delineation immediately with its identification according to the set legend (or in fact make the identification decision while the boundary is being drawn) it is important to keep these two steps conceptually separate because of the different criteria and considerations involved. The manner by which the delineation and identification processes are done in visual image interpretation may be considered almost unique to the science and art of remote sensing. The initial step is to set aside what the image does not represent and home in on what are the realistic identification alternatives in each given instance. This enables immediate concentration of

attention on the evidence and characteristics of the images that discriminate among the candidate identifications. Thus it is essential to emphasize to the student the importance of his own preparation for visual remote sensing interpretation by developing a sufficient understanding of the ecology and components of the landscape so that he knows what to expect and can quickly rule out the possibilities that are ecologically or biologically inconsistent with the scene. The importance of this point is one of the reasons why we earlier emphasized the value of a natural resources disciplinary orientation as essential background for training the most capable image analysts of renewable natural resource conditions. Knowing what to expect on each landscape is generally the major key to success.

GENERAL PRINCIPLES, TECHNIQUES, AND EQUIPMENT*

Since this phase of the classroom instruction deals with the very fundamentals of photographic interpretation, the instructor would be well advised to begin it by ensuring that each student has a clear understanding of the meaning of that term, adapted to the broader context of visual interpretation of all image types. "Photographic interpretation", as officially defined by the nomenclature committee of the American Society of Photogrammetry, is "the act of examining photographic images for the purpose of identifying objects and judging their significance". This is obviously expandable in scope to all kinds of visually interpreted imagery.

Most photo interpretation is done from vertical photographs, and the vertical view presents objects on the Earth's surface in an unfamiliar aspect. To work with the vertical view, the photo interpreter must revise his ideas of the external world and acquire new habits of observation. Moreover, objects are imaged on aerial and space photography at very small scales. Because of the vertical view and the small scale, some elements of appearance assume greater importance in aerial and space photography than in the ground view, while others assume a lesser importance. The first requirement is that the interpreter become knowledgable about, and adjust his approach and thinking to, these differences.

A. Image Characteristics

The interpreter of aerial or space photography must learn to pay special attention to the following characteristics of photographic images.

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[*] It is recognized that many of the readers of this material will find little in it that is newsworthy. The material is nevertheless presented here for two reasons: (1) to bring those individuals who have only a limited understanding of photo interpretation to a level adequate for readily comprehending the material covered later in this presentation; and (2) to invite comment from more experienced personnel who may wish to express alternate views with respect to some of the concepts that are presented here.

1. Size

The size of an object is one of the most useful clues to its identity; by measuring an unknown object on an aerial or space photograph, the interpreter can eliminate from consideration whole groups of possible identifications. The first step toward efficient interpretation is to narrow down (i.e., to restrict) the alternatives.

2. Shape

The shapes of objects seen in vertical view can be a powerful tool, because the plan view of objects is an important and sometimes conclusive indication of their structure, composition, and function. The vertical view of a forest may reveal much as to the density of the timber stand, the number and size of the trees comprising it, and the economic and recreational value of the forest itself. The vertical view of a landform may show spectacular effects of tectonic and gradational processes. To the motorist a cloverleaf road intersection is an incomprehensive maze through which he must find his way by faith and by paying strict attention to signs; to the aerial observer, the intersection is perfectly clear in logic, form and function.

The value of shape to the interpreter is that it establishes the class of objects to which an unknown must belong; it frequently allows a conclusive identification; and it aids the understanding of function and significance.

3. Shadow

The shadows seen in the vertical view sometimes help the interpreter of aerial or space photography by providing him with profile representations of landforms or other objects of interest. The darker the shadow, the more crisply the profile is discerned.

On the other hand, objects on which shadows fall reflect so little light to the overhead camera as to be visible only dimly or not at all in aerial or space photographs. If the interpreter is interested not so much as using shadow outlines to discern profiles that will help identify a particular class of objects as he is in the landscape as a whole, he must forego some of the advantages of shadow identification in order to see as much as possible of the ground surface adequately lighted. Shadows also can have important effects on the photo interpreter's perception of depth, height or relief.

4. Tone and Color

Color perception is an important element of our awareness of our environment. In black-and-white photographs, distinctions between hues are lost and objects are observed in tones of gray. The tones of color photographic images are influenced by many factors, and the tones of familiar objects often fail to correspond to our perceptions of those objects in nature. A body of water may appear in tones ranging from green to black, depending on the angle of sun and the number of wave surfaces reflecting light to the camera lens. A black asphalt road may appear very light in tone because of its smooth surface. When the photo interpreter understands the factors which govern photographic tone, he regards the tones of objects of interest as major clues to their identity or composition.*

5. Texture

Texture in photographs is created by tonal repetitions in groups of objects which are too small to be discerned individually. It follows that the size of object required to produce texture varies with the scale of photography. In large scale photographs, trees can be seen as individuals; their leaves or needles cannot be discerned separately, but contribute to the texture of the tree crowns. In photographs of smaller scale, the crowns contribute to the texture of the whole stand of trees. In most of the photography that is taken from spacecraft, the texture of a group of objects – partially vegetated boulder fields or rock outcrops, for example – may be distinctive enough to serve as a reliable clue to the identity of the objects comprising the group.

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*Furthermore computer-assisted analyses of photographic images usually are commonly based on tone or brightness values in preference to any other image characteristics.

6. Pattern and Association

Students of the Earth sciences have always laid great stress on the pattern or spatial arrangement of objects as an important clue to their origin or function or both. Human geographers and anthropologists study settlement patterns and their distribution in order to understand the effects of diffusion and migration in cultural history. Outcrop patterns provide clues to geologic structure, and drainage patterns have orderly associations with structure, lithology, and soil texture. The varying relations between organisms and their environment produce characteristic patterns of plant association.

Many regional patterns and associations which formerly could be studied only through laborious ground observations are instantly and clearly visible in aerial or space photographs. Moreover, such photographs may capture many rather small but significant patterns which might be overlooked or misinterpreted by the ground observer--fracture traces and tonal "halos" for example. Indeed, the trained observer appreciates the significance of aerial or space photography chiefly through his understanding of patterns and associations on the Earth's surface.

B. Activities of Photo Interpretation

The photo interpreter, according to a widely accepted statement of his work, identifies images in photography and determines the significance of the objects they represent. Psychological analysis regards photo interpretation as if it occurred in a time sequence. The sequence begins with a search process which results in the detection of important images. Certain of the images may need to be measured. Measurement is followed by consideration of the images in terms of information, usually nonpictorial, from the interpreter's special field of knowledge. Finally, the interpreter must be able to communicate both his perceptions of images and the significance of the images. Five activities of photo interpretation merit special mention here, viz., use of search techniques, use of stimuli, measurement, deductive reasoning, and field checking.

1. Use of Search Techniques

A job of interpretation could be begun by close examination of all details which are thought to be relevant; but most experienced interpreters prefer to begin by scanning the area as a whole or a large part of it. It is always helpful, and usually necessary, to study the photographs with reference to one or more maps. The photographs should be plotted on an index map or overlay; or a photomosaic may serve as an index. Another map of larger scale, preferably a topographic map, should be at hand throughout the process of interpretation.

Many image characteristics may provide clues to the identity of an unknown object. None of the clues is infallible by itself; but if all or most of the clues point to the same conclusion, the conclusion is probably correct. Photo interpretation, then, is actually an art of probabilities. The principle involved here, known as "convergence of evidence" requires the interpreter first to recognize basic features or types of features and then to consider their arrangement (pattern) in the areal context. Several interpretations may suggest themselves. With the aid of photo interpretation keys, critical examination of the evidence usually shows that all interpretations but one are unlikely or impossible.

2. Use of Stimuli

Psychological tests measure two kinds of factors, stimuli and responses. In photo interpretation the stimuli are variations in the tone, texture, pattern, configuration and other characteristics of photographic images. The stimuli of aerial and space photography have meaning for those who study the Earth's surface and usually induce correct responses.

3. Measurement

Photo interpreters can measure the exact dimensions of images by means of scales and other instruments. Generally, however, measurement in photo interpretation consists of a visual estimate of the size and shape of an object; reasonably correct estimation of dimensions is essential to correct identification. Such further activities as plotting and drawing to known scales may also be regarded as a particular form of measurement.

4. Deductive Reasoning

The arrangements of images in photographs admit of systematic photo interpretation because the orderly way in which the objects are arranged on the Earth's surface permits important deductions to be made. From these deductions then, the interpreter communicates his response to a stimulus by labeling (naming or describing) the identified image.

5. Field Checking

A large body of knowledge about photo interpretation has been accumulated by patient correlation of photographic images with the corresponding features as viewed on the ground. Many established correlations are taught as basic knowledge in the various fields of photo interpretation. Nevertheless, in almost every job of interpretation there will be unknowns or uncertain conclusions which must be checked in the field. The interpreter must accept the responsibility of field checking whenever it is feasible, in order to make sure his work is right or, if it is wrong, to find out why. Some types of work require field correlation before and after the office interpretation. The amount of field work which will be necessary varies with the intensiveness and accuracy requirement of the study which is determined by the irreversibility of decisions to be made from the derived (interpreted) information, the complexity of the area, the quality of the photographs or images, and the ability of the interpreter.

CONCEPTS INVOLVED IN THE MAKING OF PHOTO MEASUREMENTS

In Figure 1, three chief rays define the positions A', B', and C' occupied on the negative by the images of points A, B, and C, when these points are photographed vertically with a conventional aerial camera. The perpendicular distance, f, from the camera lens to the film (negative) is the focal length of the camera. Figure 1 also shows the positive (obtained by making a "contact print" from the negative). The positive plane is the same distance in front of the lens as the negative plane is behind it. Note that the positions a, b, and c in the positive plane are in the same relation as the corresponding positions A, B, and C on the ground; they are in reverse relation to the corresponding positions A', B', and C' on the negative, although corresponding distances are the same in both planes. The angle which a chief ray makes with the optical axis in object space is equal to the angle which the corresponding chief ray makes with the optical axis in image space. It is for this reason that the camera is often referred to as an "angle-recording" instrument.

1. Scale

The scale S, or representative fraction of a photograph is the relation between a distance on the photograph and the corresponding distance on the ground. For example, in Figure 1:

$$S = \frac{ab}{AB} \qquad \text{(Equation 1)}$$

The larger the denominator of the fraction, the smaller the scale of the photograph. As seen from the similar triangles acL and ACL, the scale of the photograph can be determined from the relation between the focal length, f, of the camera and the altitude, H, of the camera above the ground at the instant of photography. Then:

$$S = \frac{f}{H} \qquad \text{(Equation 2)}$$

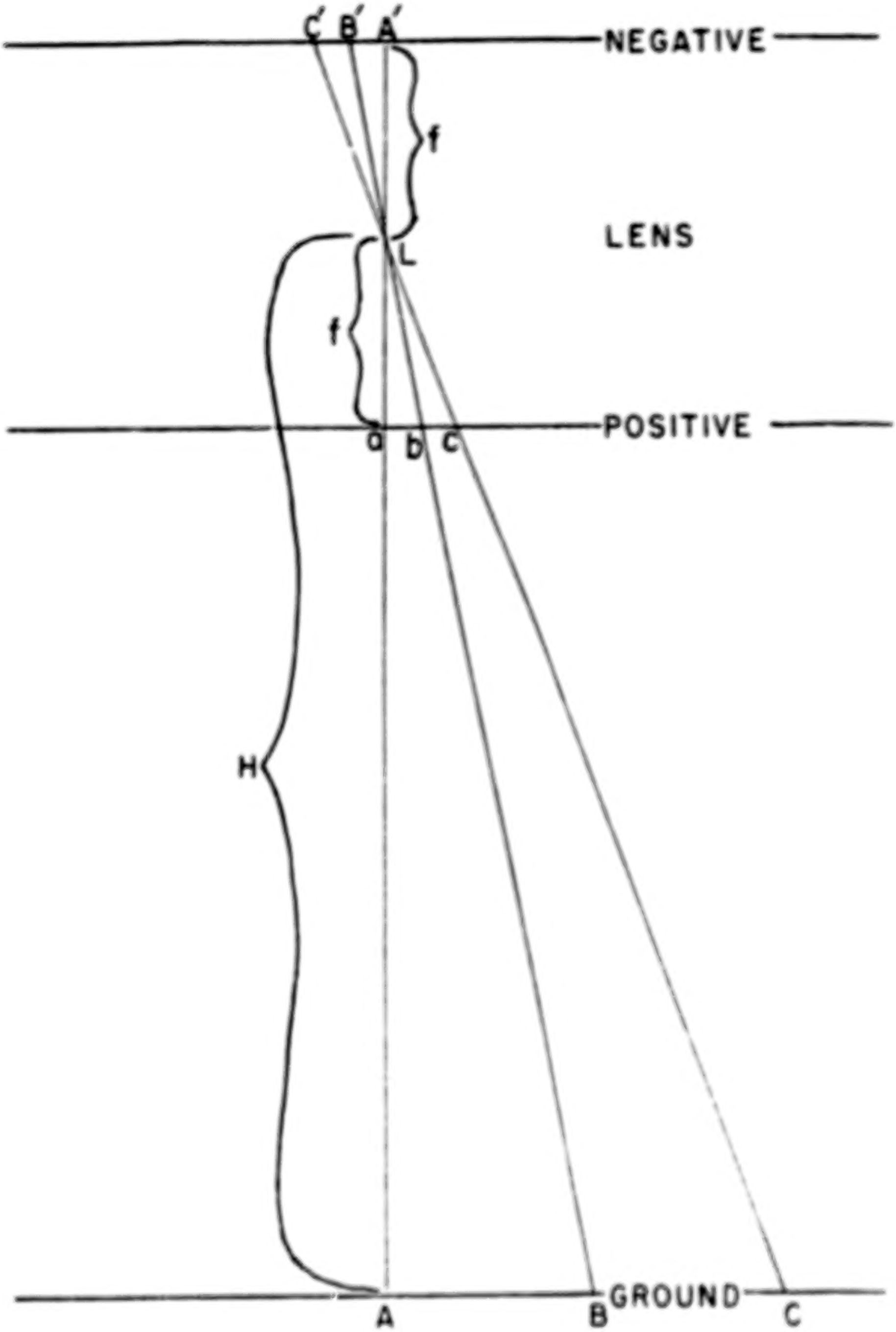
C'
B'
A'
NEGATIVE
f
LENS
L
f
POSITIVE
a
b
c
H
GROUND
A
B
C

Figure 1. Diagram illustrating how ground objects are imaged in both the negative plane and the positive plane when taking vertical aerial or space photographs.

2. Horizontal Distance

When the scale of a vertical photograph is known, it can be used to compute a horizontal ground distance (AB) by simple transposition in Equation 1.

$$AB = \frac{ab}{S} \qquad \text{(Equation 3)}$$

3. Vertical Distance

The height, h, of an object can be determined from a stereoscopic pair of vertical photos by knowing the flying height, H, at which the photos were taken with respect to the base of the object and by measuring the stereo base, P, and the differential parallax, dP, (see Figure 2) using the relation:

$$h = \frac{H \times dP}{P + dP} \qquad \text{(Equation 4)}$$

4. Horizontal Angles

A truly vertical photo of terrain that is flat and horizontal has neither tilt displacements nor relief displacements. Furthermore, there are only minimal distortions of the photographic image caused by lens imperfections or differential shrinking and swelling of the photographic film or paper. As a result such a photograph shows each feature in its correct orthogonal position, just as on a map. Consequently horizontal angles can be measured directly on the photograph with confidence that they will be acceptably accurate. When there are significant departures from the above conditions, the accuracy with which horizontal angles can be measured decreases markedly.

5. Vertical Angles

Essentially the same statements as in (4) above apply to the stereoscopic measurement of vertical angles, as when determining the slope of the terrain.

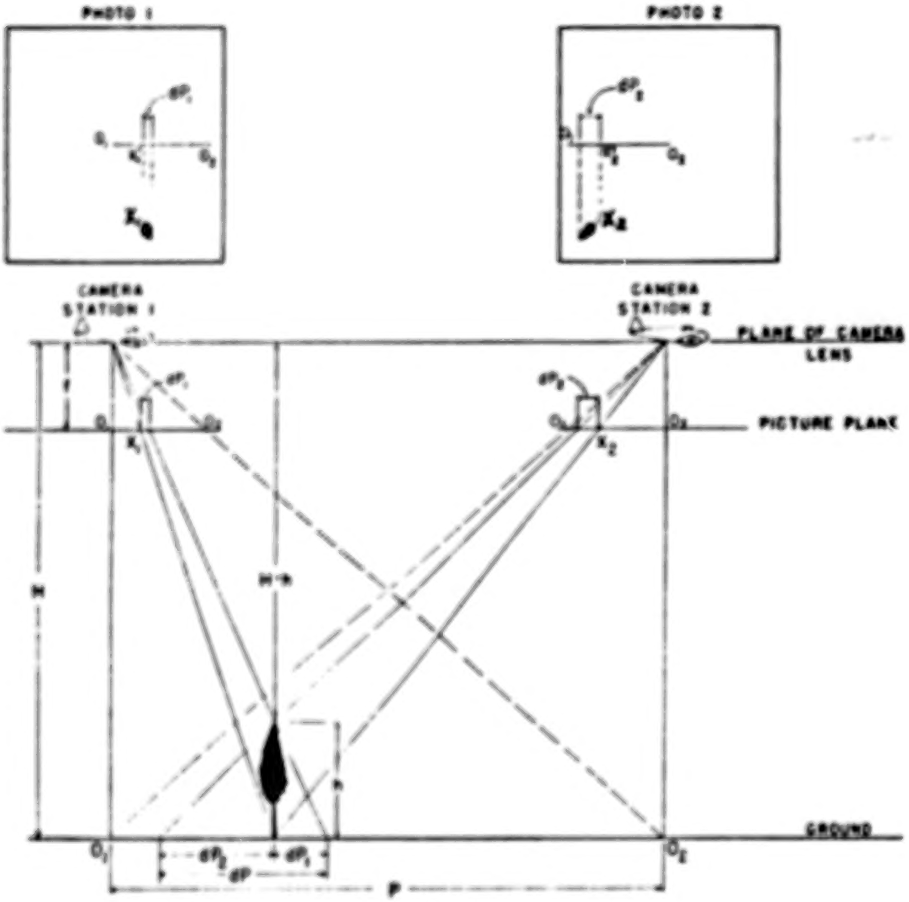
PHOTO 1
PHOTO 2
dP_1
dP_2
o_1
x_1
o_2'
x_2
CAMERA STATION 1
CAMERA STATION 2
PLANE OF CAMERA LENS
PICTURE PLANE
f
H
H-h
h
GROUND
O_1
O_2
dP_2
dP_1
dP
P

h = ht. of tree

H = ht. of camera lens above base of tree

P = Absolute parallax of base of tree (photo equivalent = $o_1 o_2' = o_1 x_1' + o_2 x_2'$)

dP = Parallax difference of top of tree referred to base plane (photo equivalent = $dP_1 - dP_2$)

From similar triangles: $\frac{h}{H-h} = \frac{dP}{P}$

Transposing: $h = \frac{H \cdot dP}{P + dP}$

Figure 2 . Line drawing showing derivation of the parallax equation.

THE NATURE AND USE OF VARIOUS KINDS OF EQUIPMENT FOR MAPPING, PLOTTING, AND THE REDUCTION OF REMOTE SENSING DATA BY VISUAL MEANS

Photo interpreters need equipment for three general purposes: viewing, measuring, and transferring or recording detail. Viewing instruments provide either stereoscopic or two-dimensional views at various magnifications; measuring instruments may be used on single photographs or stereoscopic pairs; instruments which record or transfer detail do so through the use of the "camera lucida" principle, by projection, or by means of a pantograph. This section describes several types of equipment which ordinarily are useful to the visual interpreter of photos and other forms of imagery.

1. Viewing Equipment

Viewing equipment enables the photo interpreter to scan and study photographic images. Some of these instruments permit a three-dimensional (stereoscopic) view under various magnifications; others provide only a two-dimensional but magnified view of the objects imaged in aerial photographs. Light tables help the photo interpreter to select photographs, judge the importance or quality of the photographs, find certain negatives or positive transparencies in a roll, and examine transparencies.

Because of the adverse base-to-height ratio on Gemini, Apollo, Landsat RBV, and Skylab-EREP photography, and on the side-lap portions of LANDSAT MSS imagery, only gross vertical features such as landforms that have macrorelief can be perceived three-dimensionally even when overlapping space photos such as these are properly viewed through a stereoscope. However, such viewing can greatly improve the signal-to-noise ratio of the perceived image by virtue of "binocular reinforcement" and by enabling the interpreter better to relate to the real landscape.

2. Stereoscopic or Binocular Viewing Instruments

The stereoscope, which provides the three-dimensional view of photographic images, is one of the most important instruments used in photo interpretation. The stereoscopic principle is exploited in many measuring and plotting instruments as well as in those which are designed principally for viewing photographic images. The design of stereoscopic viewing instruments utilizes lenses or a combination of lenses, mirrors, and prisms. A dual viewing stereoscope is a particular asset for training, supervision, and team interpretation.*

3. Density Analysis Devices

Various instruments are available for the quantitative analysis of the density of photographic images. These range all the way from the manually operated spot densitometer to flying spot scanners and electronic density slicers. These can be used to measure and detect areas of equal density and the latter types can be used to subdivide and give false color to a continuum of density values in such a manner that the density slices and color values correspond to features of informational interest. It requires, however, a high level of knowledge of the subjects being sensed on the part of the analyst and an intimate and purposeful interaction between him and the density analysis machine. When this interaction has identified a density range with true informational value and an allowable minimum of noninformational noise, these instruments can also be used automatically and quickly to determine acreages of the selected density values within a scene.

4. Image Enhancement Devices

The amount of useful information that can be obtained by the image analyst may be increased if the imagery is first "enhanced" by such means as density slicing, color coding, improving the signal-to-noise ratio, and combining multiple images into a single composite. Some scientists advocate the use of multiple lantern slide projectors or other optical devices for this purpose. Others prefer the use of closed-circuit color television equipment or other electronic devices. A combination of optical and electronic devices, however, usually produces the greatest amount of useful information, especially when several multidate and/or multiband images of the same area are available, each containing different kinds of information.

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* If the stereoscope has a scanning capability it is all the more useful in these three respects.

Each type of feature on Earth when it is illuminated (e.g., with beams from the sun) tends to radiate to a space-borne camera or other sensing device uniquely different amounts of energy, wavelength-by-wavelength. It follows that through the use of suitable photographic film-filter combinations each type of feature will exhibit a spectral "signature" (sometimes termed its "spectral response pattern"). One given portion of that signature becomes decipherable through remote sensing with one particular sensor and another portion with another sensor. This is true because the greater the amount of radiant energy passing through the collecting optics of the sensor (within the wavelength range to which the sensor responds) the greater the signal strength or scene brightness value that is recorded (i.e., the brighter the tone of that feature on a positive image). Herein lies the value of multiband sensing, i.e., of sensing with several sensors simultaneously, each recording in a unique wavelength band. Specifically, the greater the number of bands sensed by a multiband system (within certain limits) the greater the number of decipherable elements comprising a feature's spectral signature and hence the greater the certainty with which it can be identified.

a. Devices for the Optical Enhancement of Imagery

The most commonly used method of optically combining and enhancing multiband and/or multidate images of a given geographic area entails the making of black-and-white lantern slide diapositives, each to a common photographic scale. One slide of the set is then projected onto a screen through the use of a suitable lantern slide projector and a blue filter is interposed in the optical path. As a result, shades of grey, as registered on the lantern slide diapositive, are transformed into shades of blue on the screen. Similarly, a second lantern slide from the same set is simultaneously projected onto the screen through a second projector and is placed in common register with the first. A green filter is then interposed in the optical path of the second projector, thereby converting shades of grey as seen on the second lantern slide to shades of green on the screen. Finally (assuming in this simple instance that three images need to be combined) the third lantern slide is projected in register through a red filter, using a third projector. By this additive color process the combined images appear in full color on the screen and the particular combination of hue, value and chroma with which each type of feature is registered on the screen is directly relatable to its black-and-white "tone signature", as portrayed on the three individual photos comprising the set. Thus by examining only a single color composite image the image analyst is able to perceive "color signatures" and in this way to acquire information which otherwise could only have been obtained by making a laborious comparative analysis of tone values, resource feature-by-resource feature, on all three of the photographs.

An entirely different method of producing optically enhanced images entails the making of a "triple exposure" on a single sheet of color film that is placed in a copy camera, using as input three multiband or multidate black-and-white photographs of the same scene (see Figure 3). In the employment of this method (of which there are several variations) three filters are employed, so selected as to transmit only red, green, and blue wavelengths of energy, respectively (e.g., Wratten filters 25, 58, and 47B). When this method is used to make a color composite image from three black-and-white positives, a "triple exposure" is made on the color film as a result of our successively placing each of the three multiband or multidate photos in proper register beneath the camera and photographing each through its assigned filter. Different band-filter combinations will, of course, produce different color-coded composites. Consistent with the benefits sometimes ascribed to the use of "multi-enhancement techniques", experience has shown that one color scheme is optimum for uniquely identifying one type of resource feature or condition, while other color schemes are optimum for the identification of others.

b. Devices for the Electronic Enhancement of Imagery

Although electronic image enhancement techniques can be applied to conventional aerial and space photographs which are obtained by using photographic film directly when recording the scene, even better enhancements are sometimes obtained when the scene is recorded by means of a line scanner. The information acquired by the scanner is initially in digital mode, the digits being indicative of scene brightness values within corresponding bands.

The digital data thus acquired can be enhanced through a number of computer-aided systems and converted to image form.

The General Electric Image 100 is one such computer-controlled multiband digital image enhancement and analysis system. It displays digital data from

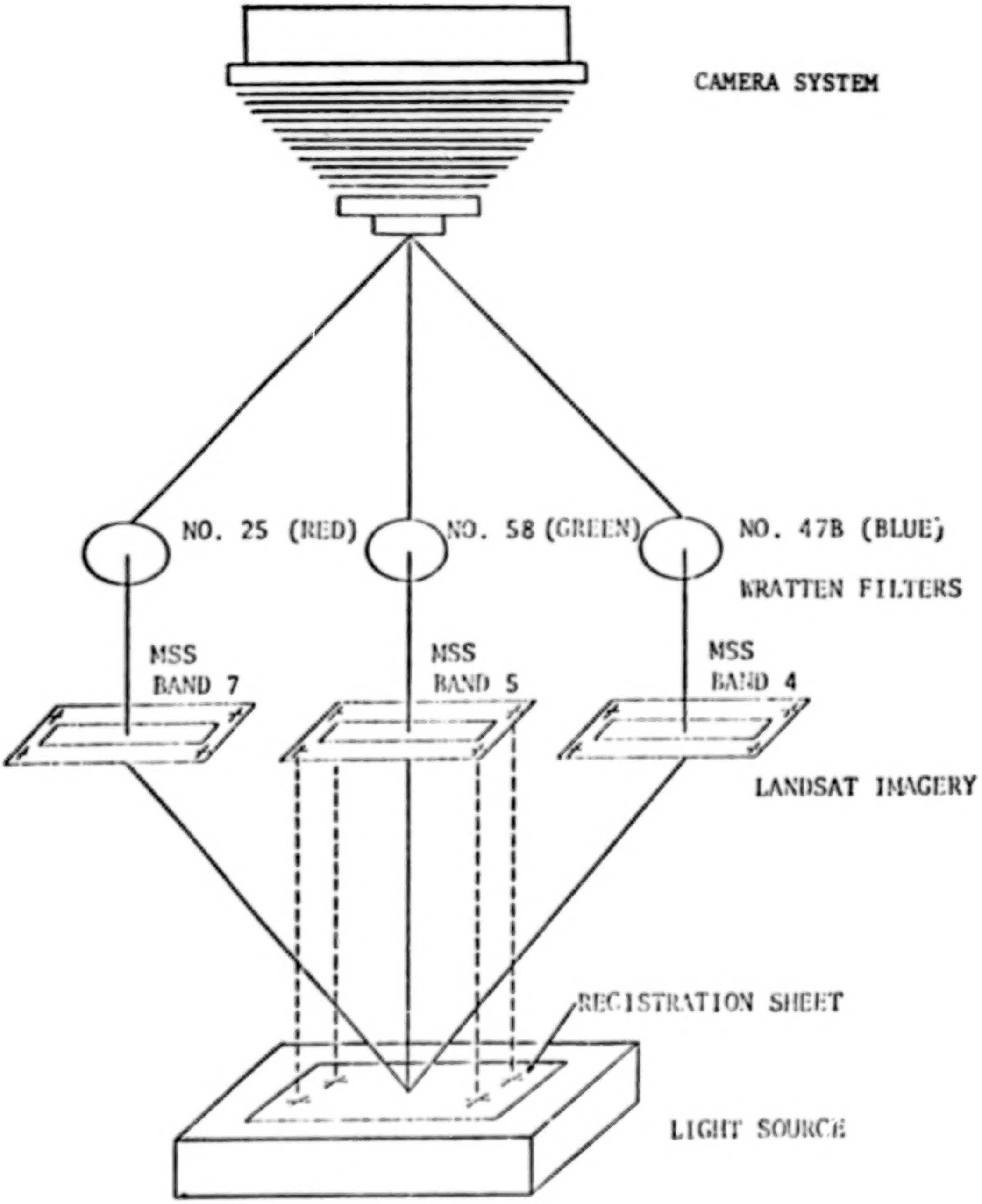
CAMERA SYSTEM
NO. 25 (RED)
NO. 58 (GREEN)
NO. 47B (BLUE)
WRATTEN FILTERS
MSS BAND 7
MSS BAND 5
MSS BAND 4
LANDSAT IMAGERY
REGISTRATION SHEET
LIGHT SOURCE

Figure 3. This schematic diagram illustrates the photographic technique for constructing color composite images. A camera, color film, colored filters, three matching frames of Landsat or other multiband/multidate imagery, a registration sheet and a light source are employed. Note that all three frames of imagery are placed separately on the registration sheet for copying. The particular band-filter combinations shown in the diagram above are used to produce simulated false color infrared composites. Different band-filter combinations will produce differently colored composites.

tapes onto a color cathode ray tube (CRT). Using its interactive capabilities, one manipulates the digital data on the CRT screen and uses nonparametric pattern recognition programs to produce thematic maps. This device allows real-time analysis and display of single date MSS imagery, applying pattern* recognition routines to enhance images and thus to identify features.

Another computer-controlled multiband image enhancement and analysis system known as "EGOR" (Electronically Ganged Optical Reproducer) has been developed by personnel of the Remote Sensing Research Program on the Berkeley campus of the University of California. Numerous other systems, all based on essentially the same concepts and principles, have been developed by various institutions and are available to users of advanced remote sensing technology.

c. The Advantages and Limitations of Various Image Enhancement Devices

There are two important advantages that are common to both optical and electronic image enhancement systems:

(1) As compared with conventional viewing equipment used by the image analyst these systems are superior in that they combine the information from several images into one single frame for interpretation purposes. The images themselves are integrated and color-coded by means of the additive color process which these optical and electronic devices can provide.

(2) The techniques used by various optical and electronic combiners facilitate the recognition, not only of spectral differences in the reflectance of features as seen on multiband photos that have been taken on a single date, but also on multidate photos that have been taken in a single band. In some

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*Until recently photo interpreters used the term "Pattern" only when referring to the two-dimensional geometric relationships of features. Unfortunately this term has since been pre-empted by computer technologists for use in referring to a feature's multiband spectral response or tone signature.

cases the enhancement of some combination of multiband and multidate photos provides the most interpretable composite image of all.

In addition to the advantages that are common to both optical and electronic image enhancement techniques, there are some important relative advantages and limitations associated with each of these two categories of techniques as compared with the other. Generally speaking, as of the time of this writing optical enhancement methods and techniques are superior to electronic ones in that: (1) they provide better spatial resolution (i.e., higher definition); and (2) they require the use of less costly and sophisticated equipment. On the other hand electronic methods and techniques are superior to optical ones in that: (1) they offer the image analyst greater flexibility in interpreting his data (e.g., very subtle grey-level differences can be "sliced", electronically "expanded", and assigned an almost infinite variety of color codes, from among which one color code may be optimum for making one type of identification and other color codes optimum for making other types of distinctions); (2) the information that is recorded on individual layers of a color film emulsion can be separated directly, suitably color-coded and redisplayed electronically in different and sometimes much more interpretable colors; (3) when large amounts of multiband and/or multidate imagery must be analyzed quickly, the electronic system may be more quickly able to present the images, ready for viewing, (in addition more analytical alternatives can be evaluated per unit of time); and (4) problems resulting from linear distortion between input images (e.g., those to be combined from sensors producing different geometry in the images) are more easily rectified electronically than optically.

One current trend in the development of image enhancement equipment appears to be that of incorporating both optical and electronic enhancement features in the same system, thereby enabling the image analyst to enjoy most of the advantages that we have just listed separately for each type.

SOME SPECIAL CONSIDERATIONS WITH RESPECT TO "CONVERGENCE OF EVIDENCE" AND OTHER PRINCIPLES INVOLVED IN THE INTERPRETATION OF AERIAL PHOTOGRAPHS

If the photo interpreter observes the image of a feature or object with which he already is familiar (or of a type which he previously has seen imaged on aerial photographs and has had its identity made known to him), the identifying of that object by direct recognition is a fairly simple process. Once he has recognized elements of the landscape that he knows to be commonly associated with such a feature or object (e.g., roads, houses, railroads or streams) a glance is enough to make the identification.

In order to identify a feature or object with which he is not familiar, however, the photo interpreter should attempt to exploit the principle known as "convergence of evidence", as mentioned in an earlier section. Few things are perfectly certain in photo interpretation in the way that one and one make two; but one particular interpretation is so probable, when all visible evidence has been considered, that it may be safely regarded as correct. The difficult part of photo interpretation consists in judgment of degrees of probability. This principle also is discussed at length in References 1 and 2.

An additional matter that was previously mentioned and which might seem to be quite straightforward, is the method used in searching on aerial photographs for features of interest. Nevertheless this is another item which merits special comment here and in the photo interpretation classroom. To paraphrase from Rabben in Reference 3:

> "There are two general ways to study aerial photography: the "fishing expedition" and the logical search. Photo interpreters have learned that aerial photography is full of surprises, and they are often tempted to examine every image in every photograph so as not to miss anything. This is the fishing expedition, a method of search that is all too frequently used. Fishing often yields large

> amounts of information, including much that is not pertinent to the subject at hand. It requires a more leisurely effort than the interpreter can usually afford to make. By resorting to probabilities, however, the interpreter can work more efficiently in the time available. He searches only those areas in which the objects of interest are likely to be found, and disregards large numbers of photographs which are not likely to contain the desired information. This selective method is logical search, a combination of quick scanning and intensive study. It demands more experience than the fishing expedition, since the interpreter has to decide where intensive study will yield the best results, but is much more productive in relation to the time and effort expended. The amount of time spent on intensive study at the expense of rapid scanning must be determined by the nature of the work. Some types of interpretation demand close scrutiny of the entire area photographed."

Among the attributes commonly found to correlate highly with photo interpretation success by any individual are his background of training and experience and his attitude and motivation toward the particular photo interpretation task that he may be required to perform. For this reason we quote, this time verbatim, another well-expressed statement by Rabben (Ref. 3):

> "Prior learning is easier to evaluate than attitudes and motivation, and its inadequacies probably easier to correct. If the interpreter does not know enough, his ignorance is usually evident to himself and his supervisor. Often, however, the supervisor is aware only dimly or not at all of his subordinates' undersirable attitudes and poor motivation, and of the extent to which these factors interfere with efficient performance. Suppose, for example, that an aerial photograph images an object x which is important for a particular type of photo interpretation. There are other objects y and z in the photograph which often occur together with (or in the vicinity of) object x. Many human factors determine whether or not a given interpreter will report object x. Assume that object x was not reported and the interpreter is then asked "What about this object?" (while pointing to object x). If the response is "That's object x. I didn't see it. I should report it," it may be inferred that the interpreter failed to find x in the photograph, either because he was careless or tired, or because the image was too small or otherwise obscure to attract his

> attention. Failure to find object x may have been contributed to by failure to find y or z, or, if y and z were found, by failure to know either that x, y and z often occur together or why they occur together.
>
> If the response is "That's object x. I saw it. I didn't think it should be reported," we infer that the importance of x is not known to the interpreter.
>
> If the response is "That's object x. I saw it. I know it's important. I didn't bother to report it," we infer a lack of interest in the job or a lack of motivation.
>
> If the response is "I didn't know what that object was when I saw it," we infer that knowledge of object x is deficient.
>
> These brief and oversimplified examples only begin to uncover the human factors at play in the activities of photo-object identification. Factors of fatigue, carelessness, knowledge of the purpose of interpretation, interest, motivation, and mastery of the appropriate field of knowledge are inferred from the interpreter's overt responses to a variety of stimuli."

Next let us discuss a few concepts that relate to the interface between humans and machines, that should exist relative to the analysis of remote sensing data.

It is true that an experienced and capable interpreter can derive large amounts of information from remote sensing imagery solely through his visual interpretation and the use of "eye-ball stereo" or only the simplest of support equipment such as good quality stereoscopes. The full power of any modern remote sensing system can rarely be realized, however, without an appropriate and intimate interaction between man and machine. Prerequisite to this effective interaction, of course, is a need for the analyst to thoroughly understand the ecological characteristics and processes on the landscape that he is attempting to interpret. The skill that derives from his knowing what to expect is of fundamental importance as he interprets the raw data or imagery into meaningful information classes.

As the interpretation of a new project is undertaken, learning what to expect and preparing oneself to convert images and data into information usually will require a preliminary trip or overflight to the project area with imagery in hand, as well as previously, to have defined a tentative legend system that is compatible both with the information needs or classes and the characteristics of the imagery to be used.

Almost any system of remote sensing will provide, relatively speaking, so much data and potential information that the primary tasks of the analyst are: (1) to achieve a very sizable amount of data reduction and generalization of the raw data or imagery into meaningful information units and (2) to separate the required information from the "noise" background that always is inherent in the remote sensing approach. His skill in achieving Task (2) rests most heavily on the depth of his knowledge and perception as an earth resources scientist, on the acuity of his powers of observation, and his deductive, correlative, and synthetic reasoning capacity. Although it is easy to teach the principles, concepts and facts relating to remote sensing technology, the real challenge lies in helping people to acquire or develop their full potential in these other, more intangible skills and abilities.

Many people feel, and perhaps it is true, that the ultimate of remote sensing capability resides in the computer analysis of appropriate multispectral data that has the ground resolution and the geometric and spectral fidelity required to differentiate the subjects of interest. Recognizing the power of such systems, as well as the tremendous flexibility of the computer itself, prompts us to make the following observations: (1) the upper limits of capability from computer analysis can be achieved only when the process of visual interpretation and other forms of man's interaction are incorporated at appropriate stages in such a way that all forms become an integral part of the analytical system. When this has been done, each component, (visual interpretation, human reasoning, and computer analysis) can be used effectively for what it is best suited to do. Consequently, each will perform those functions in which it is most cost-effective in both dollars and time when all the vicissitudes and frustrations of complex computer systems are considered. Visual interpretation is not archaic, nor will it become so, and we should thus strive to put it in proper perspective as part of the new, more sophisticated system as we design training programs and courses. (2) The same approach and the same intangible qualities of the photo interpreter that are emphasized by Rabben are equally important in the image analyst who must interact with the computer in making digital data analyses.

Another point that must be made clear to the trainee is that many kinds of information needed about earth resources and the human environment are not directly discernible from remote sensing imagery--especially in regard to the meeting of conventional or customary informational needs from LANDSAT interpretation. Such kinds of information can often be derived, however, from discernible indicators or from information surrogates. When such considerations become the mechanism of interpretation, interaction between man and machine becomes doubly important since man is the component with the ability of thought and reason. When surrogates and indicators are identified the increased efficiency resulting from landscape and resource stratification on the basis of these indicators often results in substantial gains both in the quality of information eventually derived by a multi-stage approach, in the cost-effectiveness and timeliness of the inventory, and in the usefulness of machines for the making of computer assisted analyses.

Thus far in our paper we may have been a bit too dogmatic in the making of certain assertions, thereby creating the erroneous impression that we have all the answers with respect to "the reduction of remote sensing data by visual means."

By way of disclaimer, let us conclude this section by posing a few questions for which we have, at best, only part of the answer. Surely, since our audience consists almost entirely of remote sensing educators, this maneuver will be recognized as the one which is pedagogically sound. Here, then, are a few questions followed in each case with little more than some suggested considerations that bear on the answer.

1. How does a person decide what type of remote sensing data (or combination of data types) should be utilized to meet a specified information need? There obviously are many considerations beyond the one of which data type will provide the information at greatest accuracy. Costs, access to necessary analysis equipment, timeliness, and availability of imagery, level of informational detail required, size of the project area, and probably a host of other points should be considered, weighed, tradeoffs evaluated, etc.

The list of most probable data types would include:

Aerial photography	(35mm format and on up) (B&W, color, B&W IR, CIR) (scales) (the interaction of film/filter and scale in relation to information content)
Landsat hardcopy imagery	(standard products) (enhanced images - edge, contrast, debanding) (has much application been made of synthetic stereo viewing of Landsat-Photogram. Eng. 42(10)1279 ?) (Landsat III RBV imagery)
Landsat MSS computer assisted analysis	(digital data)
Thermal scanners	(to obtain multitemporal data for the identification of features from their thermal inertia properties)
SLAR	(to obtain imagery even in cloudy weather and at night)

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Additional information bearing on this question will be found in Appendix A to this paper, entitled "Procedure for Determining the Usefulness of Any Given Type of Aerial or Space Photography in Relation to the Inventory of Natural Resources." After reading that, however, one can easily conclude that no complete and definitive answer to the basic question we have posed has been given.

2. If a person is to conduct a photo interpretation project how should he select the photo interpreter?

- what qualities should he look for?
- what mechanism should be used to screen applicants - specifically how should they be tested? (may not be practical to conduct a test which is a sample of the very work to be done because of the training involved).
- how are the selected interpreters subsequently trained?
- in a production situation, what are optimum working conditions?

Information bearing on this question appears in a companion paper that we are presenting at this conference under the title "History and Future of Remote Sensing Technology and Education."

3. What methods are available for quantitatively evaluating the accuracy of a map produced through an aerial or space photo interpretation procedure?

Here the problem is largely one of knowing for sure what to use as infallible "ground truth", because we all know of instances in which the map made by photo interpretation is more accurate than that made by direct "on-the-ground" observation. Once we know the correct solution, it is fairly straightforward to calculate the three relevant measures known, respectively, as "percent correct", "percent omission error", and "percent commission error".

4. Has the science and technology of remote sensing reached the point where we should consider a major "remote sensing degree curriculum" in colleges and universities or should it remain for the time being merely as a block of supporting study, (possibly a minor at MS and Ph.D. levels) within some basic resource-oriented disciplines such as geology, forestry, or agriculture?

5. We presume most of us could agree that visual remote sensing interpretation is very much an art and acquired skill. Experience shows that some individuals (approximately 60 to 75 percent) seem never capable of attaining the proficiency level of others. How can we as educators change this situation and more effectively educate our students in the subtleties of the art? Specifically, what does this require of us as educators?

As the authors of the present paper, and more specifically of the five questions posed above, we certainly are among those who will be interested in any answers that may be given in the Workshop Session that occurs later this week here at our Conference of Remote Sensing Educators. We will be especially interested in the way that such answers may relate to the material contained in Appendix A which touches, in one way or another, on each of the questions posed above.

SUMMARY AND CONCLUSIONS

The primary purpose of this paper has been to define the problems, state the objectives and address the issues that are most likely to be of concern to educators in the teaching of courses dealing with the reduction of remote sensing data by visual means. The paper has largely centered upon principles and techniques that are involved in the photo interpretation process and upon the means by which they can most effectively be taught within the university or college environment. If our paper serves to stimulate fruitful discussion among the various participants at this Conference of Remote Sensing Educators, our primary goal will have been achieved.

In the interest of keeping this document suitably short to serve as a working paper for discussion purposes we purposely have eliminated many relevant details. For those interested in such details and an integration of them within a suitable framework, we will conclude our paper with an Appendix. That Appendix deals with the procedure that we have found to be most effective in determining the usefulness of any given type of aerial or space photography for the inventory of natural resources. We have found that, classroom and laboratory time permitting, much of the work in a basic photo interpretation course can be centered around a step - by - step employment of this procedure. Such an instructional effort can be especially effective if, at the outset the instructor is able to (1) define for the students some specific resource inventory problem and associated resource management objective of local interest; (2) acquire suitable imagery for use in the stepwise evaluation that is to be made by each student; and (3) arrange for the resource managers, themselves, to provide a meaningful critique, once the procedure has been followed to its conclusion by the students.

APPENDIX A

PROCEDURE FOR DETERMINING THE USEFULNESS OF ANY GIVEN TYPE OF AERIAL OR SPACE PHOTOGRAPHY IN RELATION TO THE INVENTORY OF NATURAL RESOURCES

One particular type of aerial or space photography can differ greatly from another in any of several respects including the following: (1) photographic scale and associated spatial resolution, (2) photographic film-filter combination and associated spectral resolution, (3) time of day, and (4) season of year. Consequently the usefulness of the photography in relation to the inventory of natural resources can depend on these same parameters. Hopefully, those seeking to evaluate such photography will find the following stepwise procedure adequate, with only slight modification. This procedure has been successfully used on many occasions by the present writers.

A. Define the Informational Requirements of the User

Broadly stated the objective in making an inventory of natural resources is to determine, to an acceptably high order of accuracy, the amount and the condition of each kind of resource that is present in each portion of the area for which the inventory is being made. The types of natural resources commonly dealt with include timber, forage, agricultural crops, minerals, soils, water, and animal life. One of the best ways to insure success of a remote sensing application is to do a superior job in problem analysis and in specifying the information requirements in terms of data elements that are consistently obtainable from appropriate remote sensing systems. This should always be the first step. (Note Section F, following).

B. Make Spectrometric Analyses

Because of the limited spatial resolution exhibited by most small-scale aerial and space photography, the photo interpreter must place considerable reliance on photographic tone or color as an aid to determining the identity of various features, objects and conditions. Consequently, for the person who seeks to extract information from such photography, spectrometric analyses may be of value in either of two respects: (1) such analyses may reveal clearly what the tone or color "signature" (sometimes termed the "spectral response pattern") of each object or condition is likely to be on currently available photography that has been flown with some specific combination of photographic film and filter; and (2) such analyses may also suggest certain other film-filter combinations which, if used on future photographic missions, would give even more informative tone or color signatures.

Spectrometric analyses commonly are made in either of two ways: (1) through the use of spectrometers that are capable of measuring the reflectance, absorption, transmission and/or emission properties, wavelength-by-wavelength, for each object or condition of interest; and (2) through the obtaining of multiband images of an area that contains representative examples of each such object or condition and noting the tone or brightness with which each type of feature is imaged within each wavelength band. Both methods, of course, must also give due consideration to spectral transmissivity of the atmosphere and to spectral sensitivity of the remote sensing devices.

The first of these methods theoretically will reveal the precise wavelength bands that will be best for obtaining unique tone signatures in either a single band or a multiband reconnaissance system. The second method permits each "tone signature" to be measured directly from the actual imagery and thus minimizes several of the uncertainties that are inherent in the theoretical model. However, because imagery is obtained in only a limited number of bands, this second method may not precisely define the optimum band limits in terms of wavelength. During the past several years, personnel at the University of Michigan, in the Infrared and Optical Sensor Laboratory, have been compiling a highly useful library of spectrometric data for many types of features. Most of those scientists are now continuing this work while in the employ of ERIM (the Environmental Research Institute of Michigan).

C. Obtain Competent Image Analysts

Tests previously conducted by the present writers and by others, have shown that extraction of the types of information referred to in Step A can be a very difficult task. Consequently, the persons selected to determine the extent to which any given type of photography might be useful for natural resource inventory should have the proper motivation, visual acuity, patience, judgment, and background of training and experience for engaging in this task. Otherwise the results of their efforts are likely to be so discouraging that the entire concept can be seriously discredited.

The present writers have repeatedly found, when testing groups of about 20 applicants for various difficult photo interpretation tasks, that the average accuracy of their interpretations of natural resource features and types is only about 70 percent--which is scarcely adequate for most resource inventories. However, when the results of only the best four or five of these students are considered, their average accuracy commonly is found to be better than 90 percent. Let us presume for the moment that we will need 20 photo interpreters to make a particular natural resource inventory of a large area with the aid of a given type of photography. If we will select the best 20 trainees from a total of 80 to 100 students, we may be able to use such photography very effectively; but if we train only the first 20 applicants that happen to be available and then use all 20 of them in the subsequent operational phase, we probably will be greatly discouraged by their results. Their average performance is likely to be very low and the types of errors that they make are likely to be quite variable.

This factor of variability is an especially troublesome one when, as in this case, we attempt to assign to each of several photo interpreters his own particular portion of the geographic area that is to be inventoried. Once he has made his own kinds of errors in attempting to identify natural resource features and delineate type boundaries on his aerial or space photography, it becomes almost impossible for us to pool his efforts with those of other image analysts who have interpreted adjacent areas. By selecting only the very best interpreters from a large class of trainees, however, we can greatly decrease this variability problem.

D. Procure Suitable Equipment for Use in Interpreting the Photography

Traditionally, photo interpreters have considered that the equipment they need is of three types; viewing, measuring, and plotting. Of these, the type of primary concern here is that needed for viewing aerial or space photography.

At present stereoscopic viewing equipment usually is of great value for viewing aerial photography, but of only limited value to the interpreter of space photography. Because of the relatively poor spatial resolution exhibited by currently available space photography, coupled with the adverse ratio of flying height to object height, those objects which are less than about 50 to 100 feet high do not exhibit discernible amounts of stereoscopic parallax. Since most of the features which are of interest to the managers of natural resources are less than 50 to 100 feet high, a serious limitation is thus imposed. Gross landforms frequently can be viewed 3-dimensionally on space photography, yet our inability to determine accurately from such photography either the steepness of slope or the total height of landforms again makes stereoscopic viewing equipment of limited value. Given higher resolution on space photography than that provided by NASA's various camera systems would do much to remedy this difficulty.

Normally, the principal value to the interpreter of simultaneously viewing a pair of overlapping space photographs lies in the improved "signal-to-noise" ratio. This in turn is due partly to the use of twice as many silver grains to form the composite image and partly to the benefits that result from "binocular reinforcement" when assigning one good eye to the study of one image and another good eye to the study of its stereo mate.

The viewing equipment used when studying photography should suitably magnify the images and present them sharply to the photo interpreter. The maximum amount of magnification that is likely to be beneficial is roughly the same as the ratio of the image resolution to the maximum resolving power of the human eye. Both factors are appropriately expressed in line pairs per millimeter. Thus, if 80 line pairs per millimeter are resolved on the original photography and (as usual) only about eight line pairs per millimeter can be resolved by the human eye, a ten-fold magnification of the image may be about the maximum that is beneficial to the photo interpreter if he studies the imagery at his most effective viewing distance. At greater magnifications, graininess and granularity factors become so troublesome that the image of a given feature begins to "break up", i.e., the continuity of its outline becomes lost in the greatly magnified "noise" of the background, with the result that the configuration of any such feature becomes less discernible instead of more so.

E. Obtain Suitable Photography for Study

When seeking to determine the potential usefulness of a given type of aerial or space photography for natural resource inventory, the investigator would likely find that this step is the most critical one. He can greatly improve the significance of his findings merely by exercising care when selecting the frames of photography on which to base his investigations.

Ideally, in this testing stage the geographic area that is covered by the selected photography should contain several examples of each type of natural resource feature that the photo interpreter is required to inventory in an operational program. In recent years several of these areas, known as "primary test sites" have been selected by experimenters working for the NASA Earth Resources Survey Program, and accurate ground truth already has been compiled for most such areas. According to plan, ground truth has not yet been compiled, however, for nearby analogous areas which comprise "extended test sites". These primary and extended test sites would be among the most favorable areas for study, provided that they also were covered by the same type of photography.

F. Develop a Useful Classification Scheme

Most natural resource inventories entail a classification process. Boundary lines usually must be drawn to separate one class (e.g., one timber type, geologic type, soil type or crop type) from another. Consequently, careful thought must be given, when developing the classification scheme, as to what types of categories one will attempt to recognize.

As a primary requirement, the scheme must stratify into useful categories each resource that is to be inventoried. A category is useful when, in terms of the resource characteristic that is to be inventoried; (1) there is very little variability within that category (e.g., timber volume by species and size class; crop yield by species and vigor class; terrain erodibility by soil type and slope class), and (2) there are highly significant differences between that category and all others used in the classification scheme. Unless the first condition is satisfied, a large amount of ancillary information must be collected within each category, usually by costly on-the-ground observation, in order to achieve the desired inventory accuracy. Unless the second condition is satisfied, there is little advantage to making the classification because it fails to reveal meaningful resource differences, area-by-area, within the overall project boundary.

A second important requirement of the scheme is that each category be consistently identifiable on the photography that is to be interpreted. Otherwise, variability of another kind (accuracy of interpretation) may be introduced to such an extent as to negate the value of the whole classification process.

In essence, the task of developing a suitable classification scheme is one of arriving at the most favorable compromise between the first requirement (that the categories be meaningful ones) and the second (that the categories be consistently identifiable).

An example should serve to clarify the points that have just been made: Ordinarily we wish to know, for a large forest area, the timber volume by species. We soon learn, however, that we cannot directly determine timber volumes even from high quality aerial or space photography, and only rarely can we identify tree species with sufficient accuracy. In fact, extensive experience by the present writer and others has shown that these two attributes of a timber stand (volume and species) almost never can be determined consistently throughout a given area, even on the best aerial photography flown with the best aerial cameras, films and filters.

The immature scientist could easily despair at this point by rationalizing as follows: "I am told that the primary information needed by the forester is timber volume by species. Apparently neither timber volume nor tree species can be determined, even on the best aerial photography. Therefore, I will abandon further consideration of the thought that aerial or space photography might be useful for the making of forest inventories."

The mature scientist nevertheless would raise the question of whether there might be useful indicators of volume and species which he could discern on the photography. If so, perhaps these indicators would at least permit him to classify the timber resources of an area into major categories, significantly different from each other. Hopefully, within each such category the species and volume characteristics, although unknown to him at the moment, would be quite uniform. He still would need to visit representative portions of each such photo class on the ground (in order to determine its actual volume by species), but perhaps only a few such spots would need to be covered because of the variability in volume per acre by species within each stratum. Total acreage within each delineated stratum also would be needed, but this could be readily determined photogrammetrically.

The importance of our recognizing the concept of stratification that has just been discussed (whether applied to the timber resource or to almost any other natural resource) can not be overemphasized. Some indication of its importance is found by our pursuing just one step farther the previously mentioned timber inventory example. In so doing, it will be necessary to be even more specific by selecting an exact geographic area within which we might wish to inventory the timber resource.

In the state of California, where the official NASA Forestry Test Site is located, there are roughly 100 million acres of total land area of which approximately 16 million acres contain commercially valuable stands of timber--the type that we are seeking to inventory. Foresters would like to know (within five percent of the correct answer on a statewide basis) what volume of timber, by species, is present in each part of this vast area. As previously mentioned, the photo interpreter cannot consistently determine volume by species in this area, even on the best of aerial photography which may have much higher spatial resolution then will be found on currently available space photography. Yet, through the use of indicators which permit him to stratify that vast area on conventional aerial photos into homogeneous units, he is able to reduce the amount of field work required to less than 0.1 percent of what it otherwise would be, and still the five percent limit of error is not exceeded.

It is not considered to be within the purview of this presentation to discuss any further the details of California's photo classification scheme for timber resources (based primarily on stand density and size class for areas no smaller than about 40 acres). However, we certainly should be encouraged by this example to ask whether better photography (than that on which the above findings were based), by virtue of its multispectral and high resolution capabilities, might prove to be even more effective, for purposes of timber stratification and timber inventory. If so, it could reduce still further the amount of costly "field completion" work that is required to complete the inventory.

G. Make a Preliminary Interpretation of Selected Features on the Photography

As we take this important step, we must be sure to avoid merely looking for isolated "textbook examples" which might lead to an unduly optimistic conclusion regarding the extent to which certain natural resource features can be inventoried on the photography. As previously indicated, a natural resource inventory should show "how much" of "what" is "where". In any preliminary test, therefore, we should seek to provide such information in the form of complete photo interpretations, even though we may do so for only a few square miles of terrain representative of the surrounding area. By so doing, we not only will get a better impression of how consistently we can identify various resource features; we also will force ourselves to develop suitable classification schemes for those resources, early in our evaluation of the aerial or space photography in question.

H. Check the Preliminary Interpretations

Since the preliminary interpretations of the photography that is being employed will have entailed the drawing of boundary lines, the checking of these interpretations logically consists of two phases: (1) determining whether conditions within the confines of each boundary have been accurately identified (e.g., has each delineated timber type, crop type, geologic type, or soil type been correctly categorized?); and (2) determining whether the boundaries between classes have been accurately delineated.

If only a limited size of area has been studied in the preliminary phase, the checking required at this point can be accomplished entirely by field observation. (If, in fact, the area is part of a "test site", ground truth for it may already have been compiled.) However, the methods that soon will be described (in Step K) for compiling additional information or for covering larger test areas may sometimes be equally applicable in this preliminary phase.

I. Compile Photo Interpretation Keys

A photo interpretation key is reference material designed to facilitate the identification of various objects and conditions from their photographic images. Ideally, the key consists of two parts: (1) photographic illustrations of each type of object and condition as it appears on photography taken to the same specifications as those applicable to the imagery which is to be interpreted with the aid of the key; and (2) a statement of the photo recognition features for each type of object or condition as seen on such photography.

Without the first part (photo illustrations), mere word descriptions of the photo recognition features may be of little value. In fact, they may convey vastly different impressions to different readers. This is illustrated by the description which was given of how a certain kind of timber stand, containing both hardwoods and conifers, appeared on panchromatic aerial photography: "Looks like freshly ground meat with a high proportion of fat."

Conversely, without the second part (word description), merely publishing the photo illustrations may be of little value. Of the many photo image characteristics exhibited by a given type of object or condition, only one or two may be both necessary and sufficient for identifying it. Unless there is a word description which highlights these recognition features, the user of the key will be required to discover for himself what they are. This can be a very time-consuming and inefficient process.

The standards and procedures to be used in developing various kinds of photo interpretation keys were spelled out more than 25 years ago (Refs. 4 and 5). Since they are as applicable to space photography as to aerial photography, no further information regarding them need be given here.

J. With the Aid of Keys, Make a Complete Interpretation of the Selected Photography

While this step may prove to be one of the most time-consuming, it is also the one about which the least needs to be said here, in light of our preceding step-by-step discussion. As in Step G, we should strive for a complete inplace delineation on the photography of all significant resource categories that are encountered. If several photo interpreters are to share the task, care should have been taken to give each of them the same training and each must have been given the same understanding of what he is to do in classifying resources on the photographs issued to him. Also, in such instances it may later prove to be highly beneficial to have kept records showing exactly which area each photo interpreter has classified and the time consumed in accomplishing the task.

K. Acquire "Ground Truth"

As in Step H, "ground truth" should not only reveal the correct resource classification for each portion of the interpreted area, it also should accurately position the boundary line between a given resource class and each adjacent class. Consequently, it is appropriate to consider at this point the means by which such determinations might best be made. As we do so, we are likely to realize that the term "ground truth" (meaning the actual situation as it exists on the ground at the time of photography) bear unfortunate connotation for reasons indicated in the next paragraph.

It is wrong to presume that "ground truth" invariably is best obtained solely by an observer on the ground. Strange as it may seem to the uninitiated, much of this information is best obtained through direct visual observation made from a low-flying aircraft. These observations should be augmented as necessary with low-altitude oblique photography taken from the same aircraft and showing the exact locations of some of the more significant resource type boundaries.

Occasional on-the-ground observations still must be made, of course. With this requirement in mind, suitable spots at which a light aircraft can land and take off often can be selected in advance from a study of the photography. Under some terrain conditions a helicopter is superior to a fixed wing aircraft for this purpose, although it is considerably more expensive to operate and cannot travel as rapidly from one spot to the next.

L. Compare Each Interpretation with the Corresponding Ground Truth and Analyze the Discrepancies

With the aid of adequate ground truth data one can determine for every unit area, however small it may be: (1) whether or not it has been correctly classified on the particular kind of photography used in the test; and (2) whether the errors tend to be cumulative or compensating. If errors tend to be compensating, the purposes of a reconnaissance-type survey may still be adequately satisfied.

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M. Compile Data on Photo Interpretation Accuracy and Consistency

The objective in this step should be to determine the accuracy and consistency with which each important resource feature can be discerned on the photography. Where possible, these data should express results obtained as a function of (1) the visual and mental acuity of the image analyst, (2) the equipment and techniques which he uses, and (3) the quality of the photography which he interprets.

Figure 4 shows an optimum means of compiling information on photo interpretation accuracy and consistency. To simplify the explanation of how such a table is compiled and used, we have made the following assumptions with respect to the hypothetical example that is shown in Figure 4:

1. Only 5 classes of features (A, B, C, D, and E) are needed in order to make a complete and meaningful classification of the area.
2. "Ground truth" has previously been compiled (e.g., by the administrator of the test) for 100 examples of each of the 5 classes of features. (Usually the ground truth survey will also have identified at least 3 or 4 additional examples of each class for training purposes prior to administration of the test).
3. The tabular summary shown in Figure 4 applies only to the results obtained by one interpreter, using one kind of imagery, viewing it with the aid of only one kind of lighting and viewing equipment and exhibiting, at the start of the test, only the "normal" degree of fatigue.

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(Through the use of additional tests, similar in nature, realistic variations in each of these parameters usually should be made, both individually and in various combinations, and in each such additional test the results should be summarized in a form similar to that shown in Figure 4.)

When a test of the type summarized in Figure 4 is being prepared, a small numbered dot usually is placed at each of the 500 spots. The

Ground Truth by Feature Class

		A	B	C	D	E
Photo Interpreter's Results by Feature Class	A	90	7	0	0	0
	B	10	91	0	0	0
	C	0	0	100	0	0
	D	0	1	0	80	7
	E	0	1	0	20	93
Percent Correct		90	91	100	80	93
Percent Omission Error		10	9	0	20	7

Figure 4. Form used in summarizing results of a typical test that is used in determining the extent to which various types of earth resource features (e.g., A, B, C, D, and E) can be identified on a given type of photography. For further explanation, see text.

person being tested studies each spot, in turn, and merely records, opposite the corresponding number on a suitable form, the letter A, B, C, D, or E according to his interpretation of the area in the immediate vicinity of that spot. Ordinarily he also will be required to report on the form the time when he started the test and the time when he completed it, together with any other information which he considers relevant to those seeking to evaluate his performance on the test (e.g., too much noise, too many interruptions, significant obscuring of a particular feature by numbers or other annotations, test photo appears to be of abnormally good or poor quality, etc.).

An examination of the results that have been tabulated in Figure 4 permits one to draw a large number of highly relevant conclusions with respect to this specific test including the following:

1. Feature class A is rarely if ever confused with anything except feature class B, and vice versa.
2. Feature class C is identifiable with essentially perfect accuracy.
3. Feature class D is rarely if ever confused with anything except feature class E, and vice versa.
4. Unlike classes A and B, there is need for some means of substantially reducing the confusion between classes D and E (e.g., through the obtaining of photographs having better spatial, spectral, and/or temporal resolution).

A tabulation of the type appearing in Figure 4 is likely to show that some of the desired identifications have not been made to acceptably high levels of accuracy. In such instances the photo interpreter may be able to improve the accuracy through use of a principle known as "Convergence of Evidence" (Ref. 5). For example if preliminary tests show that A is too frequently confused with B, further study may show correlated features that usually are associated with A but not with B. Similarly D may in some way be related quite consistently to C, while E rarely or never is so related.

Once such a study has been completed it can serve several purposes. It will, of course, facilitate attainment of the primary objective--that of determining photo interpretation capabilities and consistencies actually achieved (preferably as a function of image quality, interpreter training, interpreter fatigue, etc.). It also may lead to revision of the preliminary photo interpretation keys so that the features or characteristics, which these extensive tests have shown to be the most consistently identifiable, will be highlighted in the key while the less identifiable ones will be listed only secondarily or entirely omitted. Finally, the study may suggest needed revision in the resource classification system to better achieve the aforementioned compromise between the categories that would be the most meaningful and those that have proved to be most consistently identifiable.

N. Devise Various Schemes for Multistage Sampling Which Will Improve the Accuracy of Resource Inventory Data

From a study of the aerial or space photography that is being tested one may find it possible to eliminate vast areas within which there obviously is very little likelihood that significant amounts of the resource to be inventoried will be found. Furthermore, the remainder of the area hopefully can be stratified into broad homogeneous classes of the types previously described. Once this has been done there still remains, in most instances, a need to determine to much higher orders of detail and accuracy certain important resource characteristics within each stratum or class.

At this point, larger scale or higher resolution photography may be flown, not of the entire area but only of respresentative portions wherein significant amounts of the resource being inventoried are likely to occur. From interpretation of this larger scale photography, additional details are learned which permit further stratification of the area in terms of its resource characteristics. Also at this point the photo interpreter may wish to select what are known as "photo plots". These are small areas (e.g., 0.5 acres) each of which falls entirely within a single stratum and for which accurate photo interpretations and photo measurements will be made (e.g., measurements of the crown diameter and height of every dominant and co-dominant tree within the area). By measuring these characteristics within each of several plots in any given stratum, a determination of variability within that stratum is made. However, it is recognized that even on this larger scale photography the photo interpretations and photo measurements may be somewhat inaccurate, thereby accounting for some of this variability. Consequently, the need for actual on-the-ground observation is recognized, even though the intent is to limit this more costly type of data gathering to the smallest possible area.

The most efficient combination of photo plots and ground plots is determined by tried and true statistical methods which are outlined in several standard reference works including the "Manual of Photographic Interpretation" (Ref. 1). Among the primary factors considered are cost per photo plot, cost per ground plot, and measurement accuracy obtainable from each type of plot.

Because the cost per ground plot commonly is about 20 times that of the photo plot, consideration recently has been given to the possibility of substituting, for at least some of these ground plots, data acquired from a helicopter as it hovers above the plot. In some instances it has been found, for example, that the accuracy of tree measurements made from low-altitude helicopter photography compares very favorably indeed with that obtained by direct on-the-ground observation. The same is true for the identification of most trees as to species. In those instances where tree species identifications are difficult to make, even on photography of this large scale, specially designed pruning poles can be used to collect branch samples from the hovering helicopter and thus to bridge the gap between remote sensing and contact sensing. Thus we see that the hovering helicopter may be helpful both in the research phase (in checking on the accuracy of space photography interpretations) and in the operations phase (in obtaining "ground truth" data for inaccessible plots without actually entailing the expense of traveling to these plots on the ground).

The sampling schemes that are developed at this stage should also give due consideration to the improvements in efficiency that might be obtained through the use of multiband spectral reconnaissance, not only with various photographic film-filter combinations, but also with imagery obtained in the thermal infrared and microwave regions of the electromagnetic spectrum. This, however, is a topic unto itself and, consequently, no further details with reference to it are given here.

O. Summarize and Report the Findings

As applied to research seeking to determine the usefulness of various types of aerial or space photography for natural resource inventory, and then following procedural steps that approximate those that have just been described, the summary should contain five kinds of information:

1. A statement of the optimum specifications for the photography that is to be used for natural resource inventory (or for the inventory of those particular natural resources with which the study has dealt).

2. A statement of the resource classification scheme which best uses such photography.
3. A summary as to the usefulness of photo interpretation keys and related reference materials that have been compiled during the course of the study, using imagery flown to these optimum specifications (the keys, themselves, ordinarily should appear within the body of the report).
4. A quantitative expression of the accuracy achieved when seeking, with the aid of keys, to identify the resource classes on space photography flown to specifications.
5. A description of the sampling methods which will provide the highest efficiency, when used in conjunction with the photography, to complete natural resource inventories.

LITERATURE REFERENCES

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3. Rabben, Ellis L. "Fundamentals of Photographic Interpretation" in Manual of Photographic Interpretation, Chapter 3, pp 109-111, 1960.
4. Research and Development Board. "Procedure for the Construction of Photo Interpretation Keys." GC-2A, pp 93-121, 1952.
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Multimedia Workshop

Joseph J. Ulliman
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Introduction

Multimedia workshop sessions were held Wednesday from 1:00-4:00 p.m. and Thursday from 8:30-11:30 a.m. On the panel were Dr. Ronald L. Danielson, Assistant Professor, Dept. of Electrical Engineering and Computer Science, University of Santa Clara, Shirley M. Davis, Education and Training Specialist, LARS, Purdue University, and Dr. Joseph J. Ulliman, Associate Professor, College of Forestry, Wildlife and Range Sciences, University of Idaho, Chairman of the Workshop. Those attending the workshop who could be identified at one time or another are listed in Appendix A.

Objectives

The objectives of the workshop were:

a. To discuss the status and determine the availability of media in remote sensing.

b. To bring out the advantages and limitations of various multimedia and machine aided approaches to teaching.

c. To discuss problem areas.

d. To determine needs.

e. To discuss costs.

f. To make recommendations to NASA.

Not all of these objectives would be completely met in an informal workshop like this. It was also understood that many of the objectives were pursued in the paper presented Tuesday on Multimedia and Teaching Machines in Remote Sensing which is included elsewhere in these proceedings.

Media Demonstration

In addition to the workshop, certain media materials and devices were demonstrated on Monday and Tuesday evenings and explained in some detail during the workshop sessions. Shirley Davis and David Paine (Oregon State University) demonstrated their slide-tape programs to a number of interested people on those first two evenings of the conference.

Media Questionnaire

A media questionnaire was distributed during the conference to get some idea of the use of different types of media and what media might be generally available to the remote sensing community. There were 31 responses to the questionnaire, the results of which are included in Appendix B.

References

Other useful reference material which came to light during the course of the conference is listed in Appendix C.

Workshop Presentations

The workshops began with the chairman noting the objectives and emphasizing some of the points from the multimedia paper presented Tuesday, especially problem areas, disappointments and goals of particular media and some needs for the future. Ron Danielson followed with a presentation on "Computer Applications in Remote Sensing Education" which is included as a separate paper in these proceedings. Shirley Davis then discussed the media aids used in training programs at LARS, how they are developed, and gave some advice for individuals who wish to develop their own programs. Her presentation is also included as a separate paper elsewhere.

Workshop Discussion

The following discussion from the workshop is transcribed partially from written notes taken at the workshops and from recorded cassette tapes. All pertinent comments are recorded, although not verbatim, except those that are not understandable on the tape. Names are associated with comments where the person was recognized.

Key words from the objectives are associated with a comment where appropriate.

Wednesday, June 28

Comment: (PROBLEM) Remote sensers are so wrapped up in remote sensing they don't have the time to develop computer expertise or capability.

R. Danielson: (PROBLEM) Computer programs or instructional material are not publishable material and therefore it is not cost effective in the use of instructor's time to develop them.

S. Davis: (QUESTION) If CAI and CMI material existed, would you use it? (Some answered they would.)

J. Ulliman: (STATUS) Doing exams with the computer is one possibility.

R. Danielson: (PROBLEM) Security of exam questions and identifying the examinee is a problem.

Comment: (STATUS) Computers can be used to grade exams.

S. Davis: (QUESTION) Does anyone else have access to PLATO? (Those from Oregon State Univ. stated they did.)

R. Danielson: (STATUS/AVAILABILITY) PLATO has 1008 terminals. CDC is going commercial with PLATO in a number of learning centers; one is in Sunnyvale by AMES where one can go and pay for a terminal; (DISADVANTAGE/COST) cost for contact time is high; you can get PLATO to play on CDC machines but I don't think you can get access to the lesson material. Development of programs by individual departments is not likely either. It takes 50 hours minimum to develop programs for one hour contact time. Funding for such development is mainly done by major funding agencies.

J. Ullman: (RECOMMENDATION) A conference is a meeting where we should be out doing the things we're talking about. Possibly NASA could fund or assist in developing CAI programs, especially now that Ron Danielson is working for them part time.

S. Davis: (COST) Speaking of time it takes to develop programs, we estimate it takes 200-300 hours just to develop one mini-course.

Comment: (ADVANTAGE) In doing mini-course type programs, there is some advantage to having the non-specialist do the narrative portion and thereby provide some personality identification.

S. Davis: (ADVANTAGE/DISADVANTAGE) Two or three of our mini-course tapes were narrated by someone on our staff. We have not done a critical evaluation of the difference but we do know that ITC people have objected to the strong midwestern accent. For local use though, the instructor probably should make the tape in order to personalize it for the student.

Comment: (PROBLEM/RECOMMENDATION) Some students would rather read narrative than listen to the tape; give the student an alternative by providing the script also.

Comment: (AVAILABILITY) Cassette driven Super 8 film system can be projected as motion picture or individual frame for programmed paced instruction; you can adjust program speed anywhere from single frame to full motion; I do not know if anyone has done this, but it does seem to have possibilities.

S. Davis: (AVAILABILITY) Purdue will be developing more mini-course series: one on visual interpretation of thermal imagery; one on collection of field data; another on geologic image and numeric interpretation of satellite data -- this will not be a detailed how-to-do-it program but will present concepts, principles and theories; another on the basic principles of photo interpretation, including stereoscopy, parallax, scale, flight planning, etc.; and lastly one on computer processing. (Responding to a question) Yes, it is a team effort to develop materials; for example, I'll work with the geologist to develop the mini-course on geology.

J. Ulliman: (NEEDS) Some people have expressed the need for large screen displays for larger audiences.

R. Danielson: (AVAILABILITY) In fact, some are using the large 76 square foot Advent TV screens like those used for boxing and football presentations.

R. Kiefer: (PROBLEM/ADVANTAGE) There is a great difference in users and some lectures are never given twice; it is difficult for me to see how slide/tapes, which essentially sets an established course, can be advantageous in such circumstances. I can see where slide/tapes would be good for student review purposes - when a student's sick or out of town, and that the slides might provide more illustrations than a text.

S. Davis: (RECOMMENDATION) Instructors could record lecture and keep their slides together in order to have available to students for review.

R. Kiefer: (DISADVANTAGE/ADVANTAGE) I am traditional and think you lose personal contact with slide/tapes. One could use slide/tapes to help explain what a conference is all about to those people who come early to a conference.

R. Whitmore: (STATUS) I have studied the audio-visual setups at Oregon State Univ. and Purdue and have developed a modular instructional approach for my course on Mechanical Properties of Wood. It consists of a series of modules which may be a combination of traditional lecture or labs, films, video tapes, independent study materials, etc.; we put some of the programs, including labs and demonstrations, on Super 8 film but most of it goes on color 3/4" video tape even taping slides and movie film. We expect the students to master the procedures. We will also be developing a remote sensing course using the same type of procedures.

S. Davis: (QUESTION) How has the role of the professor changed between the two systems?

R. Whitmore: (ADVANTAGE/DISADVANTAGE) My contact with the students has greatly increased; there is much more one-to-one contact which is mainly my doing.

S. Davis: (ADVANTAGE/DISADVANTAGE) The instructor actually has to work harder and ends up with more student contact time. All these new terms -- self paced instruction, individualized instruction, etc. -- are overlapping terms and the techniques or methods are not a substitute for the instructor; the instructor's role is altered but he cannot put out his sign, "Gone Fishing", after developing audio-visual approaches.

R. Danielson: (ADVANTAGE/DISADVANTAGE) In the beginning computer programming course at the University of Illinois, 2000 students per semester use CAI; there is one hour lecture by a Professor, two hours of CAI, one hour lesson development, and one hour program practice along with lab sections. This is an enhancement to the traditional course and is as much or more work for the instructor than in the traditional courses.

J. Ulliman: (ADVANTAGE/DISADVANTAGE) In developing AV approaches, the instructor is actually forced to do a better job; it is a very demanding process and the instructor must be very selective as to what is put on slides or tapes. I personally still spend much time in the lab to see how the student is doing, approximately seven hours per week; a TA also spends about 20 hours in the lab. There are some students who do not take responsibility for their own education and these have to be led by the hand; many of these students get behind and drop the course - up to 20%.

I talk to all of the students who drop and almost all admit they just did not do the work to keep up.

D. Paine: (ADVANTAGE/DISADVANTAGE) I had a high (50%) dropout rate in the AV course at first, but now have about a 75% completion rate.

R. Danielson: (ADVANTAGE) It is a good experience for anyone to sit down and write a set of behavioral objectives for a course and develop a programmed instruction set for a course.

R. Whitmore: (STATUS) Another thing I do which might be of interest -- I put a rheostat in an overhead projector and using gelatin filters project the light spectrum.

J. Ulliman: (STATUS) The paper presented Tuesday has a list of many sources for media materials; the EROS Data Center has a list for their materials and Purdue and NASA also have brochures. (RECOMMENDATION) Although most slide sets are not adaptable in their entirety to a local situation, individual slides and some sets may be appropriate. NASA could provide individual or sets of slides on such things as the U-2 and its operations or the LANDSAT satellite and all its systems close-up.

T. Best: (PROBLEM) NASA may not have slides of such things because they are not taking them from a teaching point of view.

J. Ulliman: (RECOMMENDATION) That's a good point; recommend NASA consider it.

G. Hull: (STATUS/PROBLEM) NASA has 2000-3000 slides at their service center and a slide copier; how to service the community is the big question; how can the community access the collection?

Comment: (QUESTION) Is there any way in which the regional centers could be provided a circulating set for those in the local area?

R. Danielson: (STATUS) NASA has some beautiful display materials also.

J. Ulliman: (QUESTION) Is there any way individual instructors could look through slide sets and request duplication of material?

Comment: (STATUS) We are not set up to do that.

S. Davis: (STATUS/RECOMMENDATION) EDC has slide sets available; possibly the other centers could do likewise.

J. Ulliman: (STATUS) R. Jay Murray said he saw references to the stereo use of overhead projectors in a Chemical Education Journal and that one article referenced the commercial development of such projectors in Germany. (The citations to those articles are included in the references in Appendix C.)

Comment: (STATUS) We at U.C. Santa Barbara use CCTV to zoom in on LANDSAT scenes on CRT; this is especially good for large audience viewing.

R. Kiefer: (STATUS) When we do computer analysis for workshops and short-courses, and especially for people coming from out of town, and the computer goes down right in the middle of an operation led us to tape things ahead of time; that way we know its going to work.

R. Danielson: (RECOMMENDATION) How many have access to video tape players? (A few responded, yes.) It might be a good idea to survey what tapes are available and make it known to the community, even if they are of different formats.

R. Kiefer: (STATUS) Almost all campuses have some form of video tape player available to which an instructor should have access.

J. Ulliman: (STATUS) EDC has a number of video tapes available.

R. Kiefer: (PROBLEM) This is a personal thing, but I have been grappling with the problem of providing slide sets for the line drawings and B & W and color pictures for my forthcoming book. Will it be a service to people, or can they do it themselves? As far as I'm concerned people can take their own pictures.

Comment: (COSTS) If you did provide slides, they would have to be very inexpensive.

J. Ulliman: (RECOMMENDATION) I would promote the idea of making complete sets of both 35 mm slides and transparencies if they were inexpensive.

Comment: (AVAILABILITY/COST) I have 36 slides made up from a negative for $3.00. When I get 4 to 5 requests for an item, I take a shot of it with Kodacolor and send the negative off to RGB Color Lab, 816 N. Highland Ave., Hollywood, CA 90038. They make positive transparencies of it from old outdated movie film; they use the loop film for as many copies as needed. The negative/positive approach like this may be the way to beat the inventory problem.

S. Davis: (STATUS) LARS set up a remote computer network project in 1975 to 6 to 8 terminals around the country for education and research purposes to train users in the theory behind computer analysis and how to use the computer. LARS also offers shortcourses directed to the analysis of multispectral scanner data and numerical analysis. These are individualized self-directed courses, not self-instructed, weeklong courses in which a variety of media are used.

J. Mairs: (RECOMMENDATION) We have given workshops for agency people using CAI. NASA could help by providing funding to rework programs so they will be more institutional in nature; that would be one way for NASA to promote remote sensing education.

Thursday, June 29

N. Short: (NEED) Can we get people familiar with the computer in three days, possibly using video tape.

R. Danielson: (STATUS) A discipline person does not need to be a computer programmer but should know the capabilities of the computer.

C. Metz: (QUESTION) We have PLATO at Oregon State University in the Music Department; could we not get on that system?

R. Danielson: (AVAILABILITY/COST) Yes. Telephone calls would be a cost and you would have to develop your own programs; best thing would be to contact a sales representative to develop programs. EXXON has CAI/CMI programs also.

C. Metz: (NEED) We have slides of scenes and want to best get across an idea; is it best to put words or a word on the slide itself?

N. Short: (STATUS/AVAILABILITY) You could have two slides - one as is and another with a word on it. NASA has one of the largest collections of slides in the world (and it is in the public domain) and would like to see them utilized. It's easy to make your own slide shows; Kodak makes a camera which fits over any 8" x 10" picture. You can produce shows by taking a standard lecture which uses slides and where the instructor is giving a spontaneous talk - tape record the lecture and keep the shown slides in order; coordinate the narrative and the slides for future use.

W. Limoine: (PROBLEM) My opinion of the slides used in the conference is pretty low.

Comment: (NEED) If there are any aids or guides for producing good slides they should be given to NASA.

Comment: (AVAILABILITY) Anyone can come and look at the slides NASA has; you can also look at the slides at the USGS Menlo Park facility.

J. Ulliman: (NNED) What about people who can't get to the facility; can provisions be made, for example a catalog of available slides?

N. Short: (STATUS) The 1st semi-annual meeting of training officers of the three NASA regional centers was held yesterday; a decision was made for each of the three centers to prepare several master set copies of slides used frequently and exchange these sets with the other centers; we would also get a brief description of each slide for a caption. I proposed a teachers guide showing B & W copies of each slide which an instructor can look at. This is basically for in-house work but I will look for some mechanism to get slides out to the public.

Comment: (STATUS) We do take slides to national conventions, like the National Science Teachers Convention, for others to see.

Comment: (ADVANTAGE) After seeing a multimedia, 6 projector presentation I was really impressed.

D. Shinn: (ADVANTAGE) Using more than one projector is useful for showing multidate imagery or simultaneously a LANDSAT, U-2 and ground scene image of the same area.

N. Short: (STATUS) Most national conventions are using two-projector setups.

J. Ulliman: (PROBLEM) What is the amount of effort required for six-projectors compared to the added information content or the message gotten across?

Comment: (ADVANTAGE/DISADVANTAGE) I am really excited about it; you do need lots of slides and it is used more at the entertainment level rather than educational; it takes 20-30 minutes to set up but it really has a dramatic impact.

S. Davis: (STATUS) Our objective at Purdue is to make a product as portable as possible and easily used by most people.

J. Ulliman: (STATUS) Multimedia six-projector demonstrations are great for gee-whiz presentations and for influencing opinions, etc. but have not proven their usefulness for instructional purposes although they could be developed for that goal.

J. Smith: (STATUS) On the life of materials - some basic material may be good for 20 years.

S. Davis: (STATUS/RECOMMENDATION) The life of most materials is short; we are committed to reviewing ours in three years; I would suggest others do the same.

N. Short: (STATUS/PROBLEM) We have made three video tapes and have only been moderately successful; the problem is amount of time to properly develop them. We taped our last course and duplicated the slides.

B. Schrumpf: (NEED) I would like to see some well-documented 20-40 minute color films produced on such subjects as, for example, the history of remote sensing, the basic energy-matter relationships, and sensor systems; some organization could do this and provide the films at a regional lending library.

N. Short: (AVAILABILITY/PROBLEM) We tried to make a video tape history of remote sensing and asked Bob Colwell to do it; time was a problem and prior planning was lacking; Bob gave an excellent presentation but it was more on "Aircraft remote sensing in California" than what we wanted - LANDSAT; the tape of that presentation is available for anyone who wants to borrow it. We are going to do two video tapes in the next six months to a year; one will be a 45 minute tape on "field observations" -- there are many people involved in developing sensors who are doing much ground work and training site selection; the other video tape will be a case history of an agency getting into remote sensing and developing an operational activity. There are problems video taping lectures; slides and other AV material must be spliced into the tape separately; its difficult to get good closeups of items off screen.

S. Davis: (STATUS/RECOMMENDATION) One way to solve that is to use a rear screen projection although that presents another problem of a hotspot on the screen. Another way is for the video production managers to have slides under his control and another video camera to view the slides; the lecturer can see the slides on a monitor. Another method is using over-the-desk mounted cameras where the instructor has control over the process. I strongly encourage those developing modules, especially when working with others, to develop definitive objectives so that the student knows exactly what is expected of him when finished; this can be an excruciating experience; if two people are working together it can be a discipline experience forcing the creators to know exactly what they are going to do.

Comment: (RECOMMENDATION) National Geographic does some outstanding films; that may be the type of thing you should shoot for in developing film as Barry Schrumpf mentioned.

N. Short: (STATUS/AVAILABILITY) Through the single-handed effort of Chuck Poulton who has gotten National Geographic into LANDSAT, the July issue will have a beautiful LANDSAT mosaic map of the Grand Canyon. They are starting to use LANDSAT in the ongoing National Geographic Lecture Series; I will ask Chuck to see if National Geographic will be interested in developing a movie. Our video facility is looking for work and I am looking for ideas for using that facility, so if you have ideas, let me know and I'll consider them.

D. Shinn: (STATUS) In the alternatives for the Washington program, which was a planning rather than remote sensing effort, KWSU video taped in color all the planning sessions. Tapes were used to inform other people involved in the effort but who were not at those sessions. The tapes were then edited into 8 hour long programs to be televised statewide. Finally they produced a highly edited film which was then submitted as one of the US entries in the UN Habitat Conference held in Vancouver.

J. Ulliman: (ADVANTAGE) When developing programmed and self-instruction packages it is a very rigorous process which is the best aid to improving instruction I know of.

R. Schultz: (DISADVANTAGE) You may also run the risk of becoming so highly organized that you go too fast in presenting material that the student can't keep up.

S. Davis: (ADVANTAGE) It is an advantage of self-paced instruction -- many have criticised our mini-courses because they go too fast, others have appreciated the stepped up pace -- if someone misses something they can always go back and listen to it over again. I would like to also ask you not to forget that print is a media also; we have developed some materials along this line.

N. Short: (AVAILABILITY) We get some requests for slides of plates from the book Mission to Earth. About 150 of the plates are on slides. There is a source of 8" x 10" color prints themselves in the Public Affairs Office, NASA Headquarters, but the quality is not the best.

Comment: (STATUS) We have inexpensive way of reproducing 9" x 9" B & W's. At AV Center we made an 8½" x 11" negative using a dot screen and then make an offset plate. We can get about 500 copies for $6.00 and of relatively good quality. We also do this for LANDSAT scenes.

N. Short: (RECOMMENDATION) Recommend you do two things: share funding for development of programs; and, identify a clearinghouse for obtaining materials.

S. Davis: (NEED) What we need is an information clearinghouse.

N. Short: (STATUS/AVAILABILITY) There are 20-30 newsletters floating around; two LANDSAT newsletters, one from Goddard and one from EDC, which have fairly wide distribution; if you have an educational announcement you can go through me because one of the members of my carpool is the editor and I can guarentee you instant access.

J. Ulliman: (RECOMMENDATION) Since NASA now involved in education, it might be a good idea to have a special newsletter to get across ideas on instructional technology, sources of materials, etc.; each instructor in remote sensing would get a copy of the letter and at the same time could provide information for the newsletter.

Comment: (PROBLEM) Such a letter though would probably be restricted to LANDSAT.

D. Shinn: (AVAILABILITY) Robin mentioned the newsletter, "Plain Brown Wrapper".

N. Short: (RECOMMENDATION) All three centers could have their own newsletter.

J. Ulliman: (RECOMMENDATION) There should be some coordination between the three centers and pass some information around nationally rather than just in the region.

Comment: (ADVANTAGE) The three centers are competing and this is desirable.

Appendix A

List of identified attendees

NAME	ORGANIZATION	ADDRESS	TEACHING INTEREST
Tom Best	Survey, CSU	Los Angeles, CA 90032	Geographic Media
B. Michael Donahoe	NASA Ames	Moffett Field, CA 94035	Service to Educators
Donald R. Floyd	Calif. Polytech. State University	San Luis Obispo, CA 93401	Geography
Garth A. Hull	NASA Ames	Moffett Field, CA 94035	
Ralph Kiefer	Univ. of Wisconsin	1210 Engr. Bldg. Madison, WI	RS and API
Ken Knothe	Treasure Valley Community College	Ontario, OR 97914	Applic. for Forest-Range Field Use
Bill Lemoine	Southwestern Oregon Community College	Coos Bay, OR 97420	Aerial Photos, Forestry & RS
Joseph Lintz	Univ. of Nevada	203 Mackay Mines Reno, NV 89517	R/S
John Mairs	ERSAL - OSU	Corvallis, OR 97331	Geography, PI & RS
Charlene Metz	Oregon State Univ.	Corvallis, OR 97331	Forestry & RS
Charles Nelson	Chico State	Chico, CA 95929	Geography
David Paine	Forest Mgt. Dept. Oregon State Univ.	Corvallis, OR 97331	Biometrics, PI & RS
Barry Schrumpf	ERSAL - OSU	Corvallis, OR 97331	RS in Resource Anal.
Robert J. Schultz	Civil Eng. Dept. Oregon State Univ.	Corvallis, OR 97331	Civil Engineering & Surveying
Duane Shinn	Univ. of Washington	410 Gould Hall, JO-40 Seattle, WA 98195	Land Use & RS
Nick Short	NASA Goddard	Greenbelt, MD 20770	Training
Jim Smith	Colorado State Univ.	Fort Collins, CO 80521	RS Computer Applic.
Moyle D. Stewart	US Geological Survey	345 Middlefield Rd. Menlo Park, CA 94025	
Frank Westerlund	Univ. of Washington	Seattle, WA 98195	RS Applica. to Land Use
Roy Whitmore	Dept. of Forestry Univ. of Vermont	Burlington, VT 05401	Forestry, PI & RS

Appendix B

Results of the Media Questionnaire

1. Use of Media

Quantitative results of the media questionnaire are included in Table 1. Of those responding, it appears most everyone uses slides, stereograms and overhead transparencies to some extent. Very few or no instructors use videotape, models, stand-alone audio tape, and computer assisted instruction (CAI). Apparently some do not use media materials even though they have them available either in their own labs or somewhere within their organizations; possibly, the materials in question are not of the proper subject material or quality to suit the instructor because, at the same time, most indicated they would use good quality materials if they were available at a reasonable cost. Most respondents also specified that they would make any media materials they developed available to others.

2. Availability of Media Materials

Many respondents made some comment that their materials were locally developed and not generally available to others because they are either not organized, not of sufficient quality or are limited to the local situation.

Those who have or could make materials available are:

a. Department of Continuing Education, Portland State University, Portland, OR.
Program: Forest Technician Series (1974-1975) Aerial Photogrammetry.

b. Crane S. Miller, California State Polytechnic University, 3801 W. Temple Ave., Pomona, CA 91768. Tele. (714)598-4513 or 4516.

Dr. Crane has developed a number of 35 mm slide sets on various aspects of remote sensing which he uses in his classes. Much of the material is not original although many slides are original

Table 1. MEDIA QUESTIONNAIRE
(Software Only)

Number of responses: Y = yes; I = infrequent; N = no.

Media	Do you use this media			Do you have this media in your remote sensing lab		If you developed or own this media would you make it available to others		If you do not have or own this media, is it available through your organization		If you do not use this type media, would you use it if good quality resonable priced items were available	
	Y	I	N	Y	N	Y	N	Y	N	Y	N
a. Videotapes	0	5	22	5	19	14	3	9	8	16	2
b. Slide sets	24	5	0	26	0	23	3	7	3	9	1
c. Stereograms	17	8	5	24	3	20	5	6	5	9	2
d. Models	1	7	17	8	15	14	4	4	10	12	3
e. Overhead transparencies	18	7	5	24	2	19	4	9	3	9	1
f. Audio tape	2	4	18	5	18	14	3	6	9	11	5
g. Slide/tape programs	5	7	13	12	11	17	2	9	8	16	2
h. CAI programs	2	2	19	3	18	13	2	2	8	10	4
i. Other programmed instruction sets	0	1	13	2	8	9	2	3	6	9	1

true and false color photos taken by his personnel. Subjects covered are: Overview of Remote Sensing (with cassette sound); Photo and Non-photo Sensors; Scale; Geomorphology; Forestry and Vegetation in General; Agriculture; Urban Land Use; and, Archeology. Dr. Crane would be interested in further development of such sets for anyone interested.

c. R. Jay Murray, ERSAL, Oregon State University, Corvallis, OR 97331. Tele. (503)754-3056.

Has developed FORTRAN programs for CDC equipment to classify LANDSAT data, select training sets, etc. These could be made available for cost of materials and copies.

d. Robert M. Newcomb, Dept. of Geography, California State Univ., Northridge, CA 91330. Tele. (213)885-3532.

For those interested, Dr. Newcomb has a list of "Selected LANDSAT Photographs of Denmark" available from the EROS Data Center as of Winter 1976/1977 with comments on coverage and quality.

e. Floyd Sabins, (UCLA, USC, Chevron) Box 446, La Habra, CA 90631. Tele. (213)691-2241, Ext. 2370.

Floyd Sabins is currently preparing a lab manual to accompany his new text, "Remote Sensing, Principles and Interpretation". He is also considering developing a slide set to accompany the text and a slide set to accompany the instructors guide for the lab manual.

f. Duane Shinn, Urban Planning JO-40, University of Washington, Seattle, WA 98195. Tele. (206)543-1508 or 4190.

Dr. Shinn has two slide sets available:

(1) "Remote Sensing of Land Use for Noise Abatement" (USAF); 192 color 35 mm slides developed March 1978 of variable quality; a case study with results of Fairchild and McChord AFB.

(2) "Introduction to Remote Sensing"; 160 color 35 mm slides developed March 1978 of excellent quality; current state-of-the-art review on PNRC Project covering sensors, data and products.

g. Everett Wingert, Dept. of Geography, Univ. of Hawaii, Honolulu, HI 96822. Tele. (808)948-8463.

Has over 100 overhead transparencies, mostly of LANDSAT and aerial images. Also has contact size negatives of these both in halftone and continuous tone. He does not have a complete list of the transparencies or a mechanism for reproducing them commercially. If others are interested though he would make special arrangements for getting duplicates.

3. Other Possibilities

Some other instructors in remote sensing may have media materials although they were not at the conference, nor were they surveyed to determine exactly what they had. Their names were listed as people who have media materials and might want that fact to be known.

a. Dr. David Simonett, Dept. of Geography, UCSB.

b. Dr. John Jensen, Dept. of Geography, Univ. of Georgia, Athens, GA.

c. Dr. Jon Kimmerling, Dept. of Geography, Oregon State Univ.

d. John Harper and Bob Plank, Dept. of Geography, Humboldt State Univ.

e. Dr. Mel Stanley and Dr. James Huning, California State Polytechnic Univ.

f. Pacific Northwest Regional Commission Land Inventory Demonstration Project, 1205 Washington St., Vancouver, WA 98660.

Appendix C

1. Catalogs, Mimeographs, Pamphlets, Workbooks

Announcing a New Series of Slide-Tape Presentations on Using Aerial Photography for Natural Resource Management. Forestry Media Center, Oregon State University, Corvallis, Oregon. (Pamphlet)

EROS Data Center Workshop. Exercise File. June 15, 1978. 21 pp. (Mimeograph)

Film Catalog 1978-1979. NASA-Ames Research Center, Moffett Field, CA 94025. (Catalog)

Mini-Course Series on Fundamentals of Remote Sensing by the Laboratory for Applications of Remote Sensing. Purdue University, West Lafayette, Indiana. (Pamphlet)

NASA Educational Publications. Aug. 1976. NASA, Washington, D.C. 20546. (Pamphlet)

Secondary School Social Studies Project "What's the Use of Land?" by the Jefferson County, Colorado, Public Schools. NASA, Wash., D.C. 20546. 57 pp. (Workbook)

2. Other References

Clarke, Paul F., Helen E. Hodgson, and Gary W. North. 1978. A Guide to Obtaining Information from the USGS. 1978. Geological Survey Circular 777.

Crozat, Madeleine M. and Steven F. Watkins. 1973. Overhead Projection of Stereographic Images. Journal of Chemical Education 50(5): 374, 375.

Hayman, H. J. G. 1977. Stereoscopic Diagrams Prepared by a Desk Calculator and Plotter. Journal of Chemical Education 54(1):31-34.

Nixon, W. D. and R. E. McCormack. 1977. LANDSAT: A Tool for Your Classroom. Reprint from: Social Education. Official Journal of the National Council for the Social Studies. Nov-Dec. 1977.

Ophir, D., B. J. Shepherd, and R. J. Spinrod. 1969. Three-Dimensional Computer Display. Communications of the ACM 12(6):309, 310.

DISCIPLINARY ACADEMIC WORKSHOPS

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FORESTRY, RANGE AND ECOLOGY WORKSHOP

Panel Members: Dr. Paula V. Krebs, Chairwoman
Dr. Charles E. Poulton
Dr. Barry Schrumpf
Dr. Frederick Gerlach

The Forestry, Range and Ecology Workshop on remote sensing addressed three major concerns: (1) increased development of remote sensing education in the community colleges, (2) improvement of the existing capabilities of the four-year university to provide educational opportunities in remote sensing at the undergraduate and graduate levels, and (3) constructive comments for the specific activities of CORSE-79.

Present instruction generally emphasizes aerial photo interpretation and photogrammetry because these are the dominant applications students are called upon to perform on the job. A significant number of students are enrolled in aerial photo interpretation courses in the community colleges and universities of the Western region. An estimate is 300 students per year in the community colleges and 550 students per year in the universities. Courses in photogrammetry, forestry-range applications, introductory remote sensing, and advanced topics in remote sensing draw 300-450 students per year.

The responsibility for the proliferation of remote sensing teaching is at the local level within the educational institutions. The enthusiasm and initiative already resides on the campuses. From this educational system has come the personnel of NASA and the federal, state and local agencies who are applying the techniques of remote sensing. Those involved in remote sensing education have a working knowledge of the topic but need to maintain a handle on the more recent developments and techniques, and the direct/potential applications of these techniques. Only then can these concepts and applications be infused to the course content. The question each instructor has to answer is what information can be introduced and at what level of the student's educational experience.

One professor reported that, while he has had experience in working with satellite imagery from Landsat 1, he dropped coverage of this subject from his instructional program. CORSE-78 has stimulated him to put it back in. The problem always, however, is in setting priorities between what is necessary to cover and what would be nice to cover in fixed credit hour classes oriented to serve a specified discipline.

Major contributions NASA could make to this process are support for teaching resources and materials, and an inter-library loan of publications and special instructional materials. Intensive short courses and training courses for instructors which emphasize the state-of-the-art are needed for the community college and university instructors.

There was substantial feeling that a large gap exists between "the rest of the campus" and the remote sensing professors. Responding to this situation, the suggestion was made that NASA sponsor a Sigma Xi lectureship by a truly outstanding speaker and knowledgeable scientist (or a small group of such speakers), and organize a lecture circuit to inform campuses generally about the state-of-the-art in remote sensing technology. This would effectively illustrate the dynamic nature of remote sensing and would help in obtaining administrative support for further curriculum development.

There was general concurrence on the need to strengthen internal support for remote sensing teaching, whether by incorporation into existing courses or new offerings.

A general discussion of course content resolved that the basic theories are introduced, followed by a hands-on experience in the laboratory that illustrates the techniques. A problem-solving approach is often stressed as a student project. Almost all courses defined the necessity for field experience in support of the in-laboratory exercises. The real world situation is the best criterion of properly applied techniques of remote sensing, be it aerial photography, satellite images, active imaging systems, or computer-aided analysis of remote sensing data.

One speaker expressed the view that some computer-assisted analyses of Landsat--and to a degree other promotion of the Landsat system--are not always held in high regard. The reason often is the minimum-to-adequate ground verification work going into some applications projects. Avoiding repeats of these situations needs careful attention in technology transfer activities.

Could or should the Office of University Affairs restructure its program? Historically, this program has been focused on direct applications that impact the decision process of state and local agencies. This has not had a strong instructional thrust but through this program the competence of instructors in the funded universities has been maintained. Several examples were cited in forestry where the funding provided by the Office of University Affairs instigated a problem assessment, a direct study toward that problem, and the practical use of the derived information. This encouraged close interaction between instructors and students (mostly graduate students) and was a contribution to remote sensing education. It is achieving technology transfer. The concensus was that the program funded by the Office of University Affairs is a sound and effective one. NASA should concern itself with providing more direct support where the needs lie as previously stated. At the present time, the most critical need seems to lie in actions and programs that will stimulate, encourage and enable a stronger thrust in education and training without strongly modifying the traditional thrust of the University Affairs program.

It was suggested that NASA should have a program expressly for the teaching function. As a prelude, it was mentioned that teaching in the university has long parasitized off from research. This has had certain adverse impacts on progress in the teaching area. A positive program could include such things as grants for equipment for development of teaching programs, making available better working materials for illustration and laboratory, and providing better access to many important reports which are traditionally produced in limited numbers. It was also pointed out that some states have been particularly successful in satisfying the remote sensing training needs that do exist without much input from the federal agencies. Such activity has even reached into the vocational agricultural teaching program in high schools and already into certain community colleges. The speaker urged more initiative and commitment on the part of the states and the academic institutions themselves.

What happens now to the loose association of remote sensing educators with NASA and, specifically, relative to this group involved with forestry, range and ecology? What will happen as a result of CORSE-78? Many attendees of this Conference feel that an immediate response by NASA which is sympathetic and supportive of the defined needs will serve as an encouragement for the continuation of the concept of CORSE-78. One contribution that would impact curriculum development on all campuses is assistance to gain internal support of administration and academic departments through information dissemination to all applicable segments of academia. An intense effort should be started to plan and organize CORSE-79.

As one guidance for CORSE-79, this group emphasized an agenda built around restricted topics handled on a workshop basis. Even recognizing that new people may attend, the conference should depart from the gee-whiz general discussion approach and deal with specific questions and challenges. Some of the group felt that CORSE-78 may have allocated too much time to formal papers, not enough to discussion. On the other hand, the newcomers felt the balance was quite good.

Workshops should be structured to address concerns of specific disciplines. Forestry, range and ecology emphasis should provide a focal point for workshops in each of the following areas:

1. Software-hardware (sources, cost, locations of operational installations);
2. Physical and theoretical concepts of sensor systems (color infrared film, other passive systems, active systems, etc.);
3. State of the sensor platform development (newly established and future plans with specifications);
4. Data availability for educational materials directly applicable to discipline orientations;
5. State-of-the-art of technique applications to forestry, range, ecology, resource management, and land-use planning;
6. Discipline group discussions for course content defining need-to-know, nice-to-know, gee-whiz motivation examples, data needs, and software-hardware needs.

CORSE-78 should include as part of the general session the status of the employment scene as well as discipline oriented sessions to stress employment credentials as required by federal, state, local and private employers. CORSE-79 should have a provision for a hands-on experience of some type of computer-aided analysis system for those attendees who have not had this opportunity. For example, the workshop prepared in conjunction with the Landsat-C launch was referred to in a very complimentary manner, suggesting that something similar to that exercise could be incorporated into CORSE-79.

More than one of the community college representatives reminded us how frequently people who are knowledgeable about remote sensing use so much undefined and new jargon that they fail to communicate, even on some of the most familiar topics.

In summary, CORSE-78 has provided a forum for the exchange of ideas and the improvement of communication among the remote sensing community involved in instructional activities. Future activities of an on-going CORSE program would contribute to the expansion of remote sensing education by consolidating the new scattered segments of effective instructional techniques. The first step is to establish the mechanism of intensive and current information dissemination to the professionals who are thoroughly versed in the concepts and utilization of remote sensing data.

GEOLOGY/GEOPHYSICS WORKSHOP REPORT

F. F. Sabins, Chairman
Chevron Oil Field Research Company

C. E. Glass
University of Arizona

Joseph Lintz
University of Nevada

John Miller
University of Alaska

Attendees at the workshop are shown on the attached list. Each of the four panelists (listed on the title page) gave a short presentation of the remote sensing programs at their institutions and described their teaching methods. The content and organization of the courses are very similar and the description submitted by Sabins is representative.

Preparation and Employment of Students

There was agreement that courses in remote sensing are valuable assets for graduates as they search for employment. There was little support for the concept of a professional remote sensing specialist. The oil and mineral industries emphasize a strong earth science background. The ability to interpret land use categories, in addition to geology, is an asset for employment in various government agencies. There is also need for remote sensing technicians to support the professionals. Technicians could be trained at two-year colleges.

At the undergraduate level there is little or no requirement for training in digital image processing techniques. At the undergraduate level, students should become aware of these methods through "before and after" examples, but hands-on training is not needed.

Teaching Aids

The requirement for an introductory textbook may have been satisfied by recent publications. There is a need for a laboratory manual and at least one instructor (Sabins) is working on a manual.

There is an urgent need for low-cost, and good quality imagery (especially color) that can be issued to students. NASA should consider mass-production of inexpensive lithographed images that could be purchased for class room use. Several instructors noted their need for imagery that covers their local area. NASA has understandably emphasized Landsat and U-2 imagery; however, examples of other image types (radar, thermal infrared, and low-altitude photography) are also needed, especially if the various images are acquired during the same season.

Faculty Training

To keep abreast of new remote sensing systems and applications, instructors need periodic training and updating. Attending meetings and listening to papers that describe new developments does not enable one to pass these methods along to students. The following solutions to this problem were suggested:

1. A "Distinguished Lecturer" program - Leading remote sensing specialists would be supported by NASA to present lectures and short courses at participating institutions. By rotating the assignment to different individuals, the participation may be improved. The American Association of Petroleum Geologists conducts such a program and could provide guidance.

2. Advanced training courses for groups of instructors.

3. Internship program for individual instructors to spend time at NASA facilities and engage in significant research.

Some faculty training could be accomplished at future CORSE or related meetings.

Future CORSE Meetings

Several participants offered the following suggestions for improving future CORSE meetings:

1. Conduct a remote-sensing field trip similar to the one at the Landsat-3 workshop.

2. Some of the presentations during the first two days could have been summarized in a printed handout and freed time for other activities.

3. Provide more time and facilities in the workshops for teachers to demonstrate their techniques and materials. In the short Geology-Geophysics workshop, several participants picked up tips that they plan to employ in their courses.

PARTICIPANTS - GEOLOGY/GEOPHYSICS WORKSHOP

Name	Organization
Floyd Sabins	UCLA, USC, Chevron
Charles Glass	University of Arizona
Joe Lintz	Mackay School of Mines - Reno
Cheryl Jaworowski	U. C. Berkeley
Ken Kolm	South Dakota School of Mines & Tech.
Moyle D. Stewart	U.S. Geological Survey
Ernest I. Rich	Stanford University
Charles L. Smith	USAF Academy
Gilbert T. Benson	Portland State University
K. Jeyapalan	California State U. - Fresno
Bert L. Conrey	California State U. - Long Beach
Joe Colcord	University of Washington
Robert J. Schultz	Oregon State University
John Miller	University of Alaska
Nick Short	NASA - Goddard
Jim Smith	Colorado State University
W. T. Finch	San Diego State University
Scott Davis	NASA - Ames
Bill Likens	NASA - Ames

RESPONSE TO OBJECTIVES OF GEOLOGY/GEOPHYSICS WORKSHOP

Comments by Jan Cannon and John Miller

University of Alaska

a) Graduates in the Solid Earth Sciences should have a broad background in the earth sciences. The curricula are designed to be flexible to support specialization during the 3rd and 4th years. Courses emphasizing remote sensing basically are structured on an interdisciplinary basis. Students from non-geoscience programs need to work with data from sites oriented toward geology as well as their own, and vice versa. Geoscience majors particularly need to appreciate the effects of vegetation upon landforms.

b) Demand for trained individuals includes two categories — disciplinary specialists and technicians. Specialists with a scientific background are needed to do the mapping, but a professional geologist, for example, is not needed to organize and search for data, generate retrieval activities or produce reproductions in suitable formats. Technicians are valuable to support the archival and retrieval functions of a remote-sensing project. The market for good performers is encouraging and nearly all such graduates find related work if they are able to produce land-use and resource-survey maps to support the goals of the employers. In Alaska these tend to be state and regional governments, environmental and geoscience consultants, the mineral and petroleum industries.

c) Needs for teaching and research:

1. No costly equipment needed for lower-level core courses, but presently hindered in considering advanced, specialized courses in digital satellite-data analysis because there is no equipment for digital clustering and display in Alaska. Work also should be done to teach techniques for digital registration of images from satellites and radar, which would require equipment not within foreseeable budgets. Equipment to digitize radar images so one could demonstrate sophisticated enhancement and interpretation from the images themselves would also be necessary if we were to expand instruction into the upper level courses.

2. Staff needs could best be supplemented by additional support for instructors for the undergraduate level courses. This would make the existing senior staff have time available for making new starts in the advanced course direction.

3. Funds, in addition to equipment and staff needs, could be utilized to prepare a syllabus. Perhaps some of the new text books just coming on the market will help alleviate such a need, but instruction tends to follow class notes prepared according to the preferences of individual instructo•s. These usually are not well enough organized and typed to warrant reproduction for student use directly. Funds for more secretarial support would be very helpful.

4. The greatest current need is for a variety of economically obtainable data tailored to some specific sites in Alaska. Presently, we have color-infrared photos from one place, radar imagery from another, and thermal-infrared imagery from elsewhere. A broad spectrum of data formats should be acquired from various Alaskan sites within a narrow time frame so students can compare, correlate, and integrate the data types to recognize the strengths of each media and to better understand the best application for each. This type of data package is available, for example, from Mill Creek, Oklahoma, but this is not optimum for instruction for students who likely will start their professional careers in Alaska. We need data packages from sites such as the DeLong Mountains for geoscience applications, plus others to include urban, agricultural, and vegetative-dominated regions. There is a growing tendency for the government to withdraw subsidization of remote-sensing data distribution; therefore funds for data reproduction are a growing problem.

d) Government agencies can best help our program by subsidizing the acquisition of time-coherent data packages as described above and by sponsoring a continuing series of distinguished lecturers who would travel from campus to campus describing current trends and new uses of remote sensing data. This would be a great help to students in the hinterlands. Perhaps NASA could pay the salary for a year of some of the most expert workers in the field and provide travel funds to present a one to three hour seminar at cooperating institutions. Individuals could be recruited on a rotating basis to not cause too drastic an interruption in their career goals.

e) Alaska is a region lacking close ties by virtue of distance. Educational materials can be obtained from distant sources with little penalty other than a longer lead time for delivery. Distance does present real barriers if one wants technical assistance and especially for those services not available here. The fact that one can locate specific sources for services 'outside' is not always very satisfying, for most projects require interaction by analysts which entails costly travel. A future need for Alaska is the establishment of a regional center for remote-sensing research and applications. Such a center could serve the needs of all users, whether they be academia, public or private agencies, and whether those needs be for data, data processing, data interpretation, or technical assistance. Means should be sought to combine the resources of existing agencies to meet a wide spectrum of needs without wasteful duplication or specialized fragmentation.

Currently in Alaska, remote-sensing data is available from a number of sources, each of which specializes chiefly in one type of data only. Technical assistance and services are available on a limited basis from a research institute of the University of Alaska in Fairbanks, which also maintains the most comprehensive library of data in the State and functions as a regional outlet for the EROS Data Center in Sioux Falls.

Agriculture, Soils, and Hydrology

Discipline Academic Groups: CORSE 78

by

Donald G. Moore, Chairman, South Dakota State University
Fred Westin, South Dakota State University
Robert N. Colwell, University of California, Berkeley

Discussion Group:

Sue Atwater, Univ. of Calif./Santa Barbara
Robert Colwell, Univ. of Calif./Berkeley
Bruce Frazier, Washington State University
Don Moore, South Dakota State University
Greg Moore, Univ. of Calif./Santa Barbara
Paul Seevers, Univ. of Nebraska
Bill Wake, Calif. State/Bakersfield
Gary Washburn, San Bernadino Community College
Fred Westin, South Dakota State University

Short Summary

Our committee feels that for discipline-oriented scientists remote sensing is best used as a tool to aid in obtaining information for the discipline. The establishment of a degree-granting curriculum in remote sensing thus is not recommended. However basic courses in photo interpretation and remote sensing fundamentals should be taken by resource students. Specific applications for remote sensing could be introduced as a part of many existing resource courses.

NASA can aid teachers both in the basic photo interpretation and remote sensing courses and also in the discipline application courses by:

1. making imagery available
2. supplying equipment
3. teaching short courses for "hands-on" experience for teachers.

OPENING REMARKS

Remote sensing, with its many techniques and innovative concepts is being investigated for its use as a tool to acquire resource information across many disciplines. This has been emphasized with the advent of space technology. Within the three broad resource disciplines assigned to our panel, the features to be observed and mapped fall into two major categories -- those which are "static" and those which are "dynamic". For example, a soils map would be considered a map of a relatively static resource since soils do not change quickly with time. The changes occurring are interpretations concerning soil potentials and limitations for certain uses. This is contrasted to a map of turbidity where the turbidity patterns continually change with time and condition. The use of repetitive analyses of these dynamic resources by remote sensing techniques display real advantages for rapid, synoptic assessments.

Remote sensing, when proven effective, has been generally accepted and in certain cases has been implemented. However, acceptance of new techniques in traditional programs has never progressed at rates which the developers of the techniques anticipate. Therefore, those technically sound, consistently accurate remote sensing techniques which are available or are developing must be documented and made available to the practitioners for their use and acceptance.

The use of these techniques for aiding the mapping of static resources to more quickly obtain basic data is just as important as for repetitively monitoring the dynamic resources. For example, approximately **two-thirds** of the counties in South Dakota presently have detailed soil surveys with projections for completion by 1986. If remote sensing proves effective for accelerating the surveys, the soil scientists can complete their surveys at an earlier date and can turn their attention to define new interpretations of the data which is the reason for the initial mapping. As we further derive the maximum benefit from our resources, demands for this type of professional service will accelerate. With remote sensing, the soil scientist may have the capability of improving his interpretation of basic soil information, i.e. evaluating crop growth or land cover as it interacts with climate and other variables on specific soils.

Dynamic resources require accurate, repetitive, and cost-effective mapping for continual updating of maps. If suitable procedures are employed, especially those where extensive instrumentation and interpreter background with the remote sensor system is not required, action and research agencies can open new avenues of information acquisition which will allow interactive analysis across many disciplines.

An advantage of the implementation of rapid and near-real-time assessment procedures in a discipline such as agriculture is that daily decisions are made at various levels from federal government to private farmers which have tremendous economic impact and which require spatial information concerning the distribution of insects, irrigation waters, weeds, etc. There already exists through the Cooperative Extension Service a network of resource professionals in an existing, proven information dissemination system who are in constant contact with actual producers. Therefore, as the technology advances to provide real-time data and adequate interpretations, a tremendous impact can be expected if we as researchers and teachers work within the existing system which is available to use and aid in deriving new information for making decisions.

Presently, the operational use of remote sensing technology is limited. However, from the federal government to the individual farmer, we can see some use being established where actual information needs exist, and where the tool is being implemented not just for an academic toy. Aerial photos have been used for base maps in soil surveys since the 1930's. We have seen federal users incorporate procedures using remote sensing in developing crop statistics and have seen producers acquiring aircraft color-infrared photography to observe crops.

If we as an academic community can provide research results which are operations oriented to provide information to existing user needs (in contrast to attempting to develop new user needs just because remote sensing can provide the information) the incorporation and use of remote sensing will continue to increase.

With this development, requirement for academic education in remote sensing technology will continue to increase. This educational need must be oriented to various levels from management to scientist to local user. Our approach must be well defined and must have full commitment of many qualified professionals to most expeditiously accomplish this goal. The task before this committee is to prepare a document, at the present state, pertaining specifically to discipline and regional needs for enhancing the teaching of remote sensing in our academic institutions. The discussion format will generally follow that provided by the conference chairman but feel free to interject with comments and questions that you feel are appropriate.

COMMITTEE DISCUSSIONS

A general feeling by discipline-oriented scientists is that remote sensing is best used as a tool to aid acquisition of information concerning that discipline. Therefore, the establishment of a degree-granting curriculum in remote sensing tends to defeat the purpose and use of remote sensing as identified. Our resource scientists should become familiar with and be able to apply remote sensing procedures as a discipline tool. We feel this will enhance the effectiveness of each graduate in his respective discipline. If we produce remote sensing graduates who have only limited discipline background, the tool will provide only limited benefit except for few instances where truly multidisciplinary staffs are available. At present, the employer requirement for individuals with even a brief introduction to remote sensing is not well established. Therefore, we need to educate the employers. This will probably best be accomplished through evolution of students possessing even a brief background of remote sensing becoming employers in the future. We do see that the demand for this skill held by solid discipline science graduates is increasing, and we encourage the students to become more familiar with the technology.

In agriculturally related undergraduate curricula, introduction of at least one course in basic photo interpretation and one course in the basics of remote sensing might be widely accepted. The course could be cross-referenced among disciplines and could be in any resource discipline where an expert exists and where the course can be handled administratively. The instructor should be a discipline specialist in one specific resource area to help in establishing his creditability. Visiting staff could provide a greater appreciation for remote sensing applications across many disciplines. The course should include such topics as the design of an operational system for solving a resource agency problem or the acquisition of remote sensing data from known sources with only a limited introduction into the theory of the technology. The instruction should emphasize the action program so that individuals will feel qualified to implement the tool in their career rather than be frustrated by the specifics of the tool. Any attempts to introduce a greater number of courses into curricula would certainly meet with resistance since most curricula already have a surplus of courses which are presently required by employers.

A change of present remote sensing instruction which could most readily advance the use of the technology is to introduce remote sensing into many existing resource courses. A geomorphologist can describe landforms through aerial photography at various stages of viewing including space-altitude remote sensors. A hydrologist can pictorally illustrate various types of drainage systems or the distribution of turbidity. Remote sensing could most effectively serve as a teaching tool while the students are gaining an appreciation for types of data and their information content. The student familiarity with the use of the tool by their college professors will yield confidence of the techniques for their continued use as they advance into action agencies or into management positions. We as instructors can orient many of our examples to serve our academic interest as well as to demonstrate that the data can be used to meet the operational needs for information by action agencies. The instructor should provide adequate background to allow the student to personally discover that remote sensing approaches can provide different types of needed information.

Within the system and demand structure presently existing, the forementioned recommendations appear appropriate. For greater action by most universities, a demonstrated demand by employers is required. This process will not quickly occur. It must be preceded by well-documented and demonstrated procedures and appropriate publishing of these procedures. NASA and other government agencies can help by supplying an imagery archive for use, recent publications, computer access, computer programs they have developed, information brochures and teaching materials on new or projected systems, etc. Assurances of the continuation of data collection and dissemination systems must be available. For the student to gain understanding of the use of specific systems, the incentive of his assurance the system will be available in the future is required.

A visible demand for increased academic exposure for remote sensing technology is documentation of required student experiences in job descriptions identifying a remote sensing background. Only few Civil Service descriptions include remote sensing. Many federal agencies ask their respective discipline professional societies to prepare job specifications. If we feel remote sensing experience can provide a valuable asset, then we in the academic institutions, who are the principle component of our professional societies, should encourage the committee charged with this responsibility to consider requiring the experience for certain levels and types of positions. If this demand is created, universities would quickly respond and include appropriate academic courses.

Advanced courses of remote sensing should include actual laboratory and field experience. Laboratories are difficult to implement for lower-level, high-attendance courses. However, appropriate avenues exist to handle small numbers of students within a given discipline through special topics credits. The development of confidence in the student for actually using the technique arises from having supervised experience in making laboratory interpretations and field verification and correction. This is true for both photo interpretation and digitally oriented courses. Often for the advanced interpretation course, a certain degree of equipment is required in additional image archives, stereoscopes, transfer scopes, computers, etc. At early stages if NASA could provide small grants or a screening of surplus property to help universities obtain this basic equipment, the courses could be more readily implemented.

As with agency staff, many university staff have not been exposed to appropriate instruction or to the experience of using remote sensing techniques. Secondly, local examples where students have studied the terrain properties should be used for maximum student benefit and these are often not available. If an appropriate course is not available with adequate teaching materials, the interested staff must develop this course and materials to meet local needs. In addition, remote sensing capabilities are rapidly changing. These factors all create the problem that to offer a quality course of instruction, a professor who already has considerable demand for his time must find additional time and finances to maintain (or develop in many instances) his academic background with an understanding of "this year's" technology. This professor time probably should be away from campus for concentrated study. This could be accomplished with a sequence of topically oriented short courses at NASA or advanced university facilities.

After the basic competence is developed, one week of short courses every summer would serve to continually update in technology advances.

These suggestions are certainly not all encompassing but a concensus of the group. We do feel the more important aspects have been covered with the more important suggestions provided. We do wish to qualify the statements for the reason that all individuals in the discussion group are presently active in remote sensing research and/or instruction. Therefore, certain of the views may contain some bias.

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Conference on Remote Sensing Educators
CORSE - 78
Stanford University

Discipline academic group workshop: Geography, Urban Planning, Land Use

Panel Members:

Merrill K. Ridd, Chairman - Geography/Planning, University of Utah
Nevin A. Bryant - Earth Resources Applications, Jet Propulsion Lab
Sen-dou Chang - Geography, University of Hawaii
Willard T. Chow - Urban Studies & Planning, University of Hawaii

Setting:

The panel members corresponded by letter and telephone prior to the workshop to develop ideas and prepare an outline for the workshop discussion. The following is a summary of the open discussion in the workshop, in which there were about 20 persons present and each person entered into the discussion. The many points brought up in the workshop are blocked into four major headings for convenience.

I. Is there an opportunity to use remote sensing in Geography and Urban Planning curricula?

Chow: Yes, but many obstacles need to be overcome, including training, obtaining materials, different needs, . . .

Bryant: Definitely, but materials need to be of the immediate area familiar to the students. Otherwise students have no concept of scale, size, or meaning of the place. Once the student has made association between the image/photo and the ground, then he/she can extend to images/photos of remote and unfamiliar places. remote sensing can be developed as an effective tool and skill in learning about geography; WRAP (Western Regional Applications Program) could make sets of material available to teachers.

Chang: Regional studies in geography could be enhanced significantly through satellite imagery of the region. This could (a) help sagging enrollments in regional courses, and (b) enrich student understanding, augmenting maps (which are abstract symbols) with the reality of imagery.

Ridd: In planning education, also, remote sensing can be valuable both (a) as a skill for inventorying and analyzing the landscape, and (b) for substantive information. For broad regional planning and resource analysis, satellite imagery has obvious utility making available information at a regional scale not accessible before. For urban planning the use is less obvious at the moment, but is becoming a usable tool that needs to be promoted.

Open discussion from the floor:

1. The urban fringe is where the action is in geography and planning. Remote sensing can be an effective instructional tool as well as an investigative/analytical tool and is beginning to be proven.

2. An example of regional resource analysis and planning in North Dakota was highlighted - serving as a training opportunity for students, a service to state and local agencies, and building up the skills and equipment of a department.

II. How can RAP help?

1. The general feeling was that RAP could help a great deal if their charter allows. There was extensive discussion about RAP's charter and its degree of freedom to support schools.

2. The question of the relationship of teaching and research emerged. The question of whether RAP could support research at all - the question of research vs. demonstration projects - the question of piggybacking some research on demonstration projects, and piggybacking teaching opportunities on both research and demonstration projects were extensively discussed.

3. Wayne Mooneyhan, Director of the RAP program at Slidell, La., emphasized that the RAP program never was meant to be a research vehicle - but a technology transfer device - a means of conveying the results of research into application demonstrations, especially through state and local agencies.

4. The question of the role of universities in this process was then debated. What does NASA expect from the universities in the RAP program? Why has the conference on Remote Sensing for Educators been called by RAP? Do they just want a discussion? Or do they want to establish a mechanism to promote RAP's interest coupled with university involvement - and how?

5. Some of the conclusions derived were that RAP (if their charter allows) could help in the following ways:
   a) Providing remote sensing material to schools and educators (in the local area and elsewhere).
   b) Support training - directly to professor, and/or indirectly through a team of educators who are well qualified in remote sensing to the many others who are not, but are interested or can become interested. This could be done at NASA/Ames and/or at major Remote Sensing schools and/or at small schools with limited facilities and skills.
   c) "Innovations in teaching" grants.
   d) Cooperate in demonstration projects promoted by RAP in the states.

   It was generally argued that these could be relatively low-cost means of transfer to schools. It was further felt highly justified for RAP, because the schools are the source of trained people moving into the market in state and local agencies.

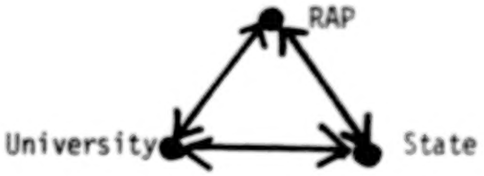
III. How can RAP and the universities best cooperate in their respective charters?

1. It was recognized that NASA's intent is to stimulate a "user driven" system where agencies are creating the need for Remote Sensing applications.

2. It was recognized that RAP's purpose is to transfer technology to state and local agencies to help create that need.

3. It was also surmised that NASA desires agencies to become sufficiently "sold" to begin funding projects through their own budgets, at least in part.

4. It was strongly argued that the universities should become and remain a part of the technology transfer system through a three-way cooperation as indicated in the following schematic diagram:



a) RAP promotes demonstration projects (and other technology transfer vehicles) in the state, and at the same time, and with equal concern, stimulates remote sensing development and training in the university by involving them as a partner in the project. This enhances NASA's over-all objective by infusing their technology immediately and directly to the state user, serving a short-term need. NASA's long-term interest is also enhanced by stimulating university development and promoting university-state interaction in remote sensing.
b) The university gains in the short-term through enhanced skills in the transfer of NASA technology, enriching faculty and training opportunities. Many universities are already strong enough to originate much of the technology and service in cooperation with NASA to the state agencies. The university long-term interests are served through the working relationship with state agencies. The university training program is enhanced to keep a flow of well-trained students ready for the growing market.
c) The state agency benefits from both NASA and university input by working on key projects in a new and efficient way. The state is assured, from the universities, of a continuous service of trained employees.

The role of RAP is assured by the continued need for innovation and transfer to states beyond the capabilities of many states to keep current with innovations through their own resources or of the universities in many states.

IV. Some remaining questions worthy of continuing discussion and resolution:

1. The following questions were prepared prior to the workshop for discussion, but were only lightly touched. They need to be explored deeply:

    a) Can RS use be expanded in resource management and planning?
        - In what ways
        - With what difficulties
        - How rapidly

    b) How can RS interface with geographic information systems (GIS)?
        - How important
        - How to expedite

    c) What RS skills are needed by the agencies?
        - BS level
        - MS level
        - Short courses

    d) What role should RS educators and university facilities play in this training?
        - Pre-service
        - In-service

    e) What is ideal course content and structure?
        - Broad or narrow in thematic coverage
        - Pragmatic or theoretical emphasis
        - How much physics (at what level and for what students)
        - Prerequisites and RS course sequences
        - Field/lab/lecture balance

    f) Course approaches
        - Local examples
        - Field observation, ground truth
        - Image processing
        - Manual exercises

    g) Facilities needed
        - Equipment
        - Space
        - Staff

    h) Incorporation of RS courses into the curriculum
        - In planning
        - In geography

    i) Extending RS into other classes in the department
        - Physical, environmental
        - Resource

    -Regional
    -Planning

j) Value of RS in teaching geographic/spatial/planning concepts
    -Scale hierarchy
    -Generalizing
    -Spatial resolution
    -Regionalizing and regional interaction

k) Integrating RS research with teaching
    -Student point of view
    -Teacher point of view

l) Attracting students from other departments
    -Pros
    -Cons

m) Communication between RS educators
    -How to improve

n) Training of RS educators
    -College
    -JC
    -High school

o) Training of decision-makers (elected officials, planning commission, etc.)
    -Material taught
    -Class format
    -Assistance from federal agencies

p) Funding
    -Material
    -Facilities

q) Assistance to RS educators
    -NASA
    -Other federal
    -State, local

r) The problem of teaching remote sensing in geography/urban planning/ land use with limited facilities.

s) The matter of mixing class/laboratory/field experience in teaching.

The matter of relating and integrating remote sensing research with teaching.

t) The prospects and/or problems of extending remote sensing education into pre-college schools.

The problems of training college (or pre-college) teachers of remote sensing.

u) The matter of materials, resources, and references in remote sensing education.

The problems or values of teaching generalizing, and classifying through remotely sensed data.

The probelms or values of teaching scale hierarchies through remotely sensed data.

v) The issue of "spatial resolution" as related to teaching geography/urban planning/land use.

A REPORT FROM THE OCEANOGRAPHY
WATER RESOURCES WORKSHOP, CORSE 78

Victor T. Neal, Chairman*

REMOTE SENSING IN OCEANOGRAPHY AND WATER RESOURCES

"Remote sensing" in one form or another has always been an important method of obtaining oceanographic data since samples and measurements have to be obtained where man cannot easily go. In recent years, especially since the satellite era began, the expression "remote sensing" has been used primarily to refer to both active and passive sensing of the earth from aircraft and/or space craft. In water resource work, especially oceanography, this type of sensing is even more remote than the traditional methods, therefore, there has been reluctance to use it even though it does have good potential for synoptic gathering of surface data and it can relay data from remote regions. It also can be used to intercalibrate instruments being used in widely separated regions.

There have been many uses of satellite and aircraft for remote sensing in water sciences. Some have been experimental only, some have been well developed and some are still in planning stages. A few examples may illustrate the variety of uses: sea ice coverage, age of sea ice, tracking of ice bergs, laser profiling of sea ice, water surface temperature, current boundaries, sea state, delineation of upwelling areas, assessment of fish and krill distribution, pollution distribution, plankton blooms, coastal sedimentation and erosion, interrogation of and tracking of drifters, location of color fronts, river plume observation, snow cover, water use rates, etc.

The equipment and techniques used vary from passive visual and infrared sensing to active methods (laser, radar/radio). Each method has its own weaknesses and strengths. "Ground truth" is essential in nearly all interpretations and must not be overlooked. Because the ocean is vast, we have no possibility of obtaining sufficient measurements at sea to match the global coverage of satellites.

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*Other panel members are listed on page 589.

One of the traditional problems of remote sensing has been cloud cover. Even though radar/radio can penetrate clouds they cannot provide all the kinds of data desired. Another major problem is that much of the oceanographic information needed must come from beneath the surface of the sea (this is also true of lakes but lakes are very shallow in comparison). In order to get some subsurface information, drifters and deep sea buoys may be used. However they are limited in that they usually cannot get information from the entire water column and they are restricted in areal coverage.

The resolution and accuracy of much of the aerial and space data obtained has been inadequate for basic oceanographic research. Nevertheless, a "broad brush" picture and trends may be observed in a reasonable time frame. Unfortunately, data for use in fisheries operation, management, and regulation must be received in real time; we have not yet achieved this except in limited cases.

The basic problems of data processing and interpretation do not differ in principle from other types of data. Computer techniques have enabled us to screen data in many ways and to reduce noise levels to the point that useful data can be gleaned from what at one time would have been considered useless records. Since data rates can be very high, the amount of data to be processed can become excessive if not properly programmed.

Recent developments of interest include the Coastal Zone Color Scanner (CZCS) on Nimbus G and the launching of SEASAT 1. The CZCS measurements provide information on chlorophyll concentration, sediment, and surface temperature and may be used for mapping productive areas, as well as exchanges between coastal effluents and open ocean waters. The CZCS is an image scanner with six co-registered channels spectrally centered at 0.433, 0.520, 0.550, 0.670, 0.750, and 11.5 micrometers. The instrument uses a fully rotating scanner which scans across track at a rate of 8.0808 rev/sec. The instantaneous field of view is 0.05 degrees, or a sea level square of 825 meters on a side. The active portion of the scan is 78.7 degrees, producing a cross track swath of 1566 km. The scan rate and instantaneous field of view are such that each swath overlaps the preceding one by about 25%. The scanner mirror can be tilted forward or backward by plus or minus 20 degrees line of sight about the spacecraft pitch axis, in 2.0 degree increments. This movement is used to avoid sun glint.

The video signal from each channel detector is amplified and filtered. Each channel is provided with an eight-bit resolution Analog-To-Digital (A-E) converter which converts the video signal into 72.73×10^3 signal level samples/sec (each sample represented by an eight-bit word). The active portion of each span will contain 1968 picture elements (pixels) for each channel.

The CZCS will normally be operated on a 30% on and 70% off duty cycle in each orbit. Commandable functions include gain change commands and threshhold offset enable/disable for channels 1 through 4 (gains can be commanded to one of four settings). Each channel amplifier electronics can be switched off separately in the event of failure of a channel, thus reducing the impact on the remaining channels.

NOAA will archive ocean color data from Nimbus G. At present a lot of color data from U-2 flights has been obtained.

The interesting features of SEASAT 1 include the following:

1) Compressed pulse radar altimeter capable of altitude to ±10 cm RMS with orbit information on geoid and time variations to ±1-2 m. It can be used to obtain significant wave height from the leading edge of the pulse.

2) Synthetic aperture radar or coherent imaging radar (50m) for observing ice, oilspills, and current patterns. It also can make computations to determine wave directional spectra and to relate wave conditions and wind speed.

3) Microwave wind scatterometer (senses capillary waves) to obtain velocities in excess of 25 m/s ±2 m/s, ±20°. It provides an entire ocean map in 12 hours.

4) Scanning Multifrequency Microwave Radiometer (SMMR) uses 6, 10, 18, 21, and 37 GHz passive radiometer which senses contributions from ocean, ice and atmosphere. Low resolution images are of about 100 km. It senses windspeeds from 10-50 m/s and SST ±1.5° K (severe side lobe problem exists) and atmospheric water for corrections to altimeter readings.

5) IRR produces thermal images (1° K) like current VHRR (atmosphere correction is not made).

At present most oceanographers, their technicians and students learn the techniques they need on their own. It is not likely that this state of affairs will change much in the near future. At present we do not know of any positions for oceanographic remote sensing specialists. Therefore, NASA should consider developing technical manuals as this group has a real need for good manuals on remote sensing applied to oceanography. It is somewhat like computer use was in its early stages. It is possible that in the future remote sensing technologists may be trained somewhat as computer programmers, etc. have been in recent years. However, it is difficult to predict future uses because technological improvements may radically change the capabilities of remote sensing devices.

It seems that the first step should be to create an awareness on the part of researchers in the field regarding the potential of remote sensing. The values of remote sensing for coastal zone management should also be presented to students in marine resource management. The basic problem is to find the best way to accomplish these tasks. There are several possible ways. One is to offer seminars on the subject to faculty and students alike. Another method is to offer short courses or survey courses for researchers so they can get a better feeling for the potential of the method. It is possible that short survey courses could be offered just before fall term registration at many oceanographic institutions; this probably could be done on a trial basis at some institutions. For students it is possible to either include some remote sensing in existing courses or to design one or two new courses for the purpose. Any of the above will require some planning and financial resources. There may be a need for very specialized studies regarding applications and interpretations not covered in the physics courses available. Nevertheless, we do not believe it is desirable that a set of remote sensing courses be developed at this time. It may also be possible to have individuals work for a short period with those workers at various centers where remote sensing is routinely being done. NASA could assist by sending speakers to give seminars at oceanographic institutions and to work individually with scientists there. Speakers have been sent out in the past. It was mentioned in the meeting that Donna Hankins, Humboldt State University, Arcata, California 95521 (phone 707-826-3731) may be able to comment on the mechanics of this procedure. NASA may also find it desirable to take people on board for short periods to gain practical experience.

Regardless of which method or methods are used for training there is a need to get meteorologists, oceanographers, engineers and remote sensing specialists together to discuss the merits and needs. The scientists need to communicate their needs so that development of needed instrumentation can be accelerated. There is also a need for more interaction within and among the following groups: NOAA (including Sea Grant and Coastal Zone Management), NASA, US Navy, US Coast Guard, US Air Force, US Corps of Engineers, US EPA, and appropriate state agencies as well as universities.

One of the problems associated with increased use of the modern techniques is the cost and availability of processing equipment. It seems that it is too expensive to have a full setup at each institution that is interested in the work. It may be that regional consortias of institutions or regional processing centers (somewhat like NCAR or UCAR) connected to remote stations are the answer. A learning center could be included in each center. Such centers could specialize in land use, weather and atmosphere, vegetation, marine uses, coastal zone management, pollution, lakes and rivers, hydrology, or other fields.

Regardless of the methods chosen for educating/training technicians as well as scientists all need some background in the technology involved and in the field in which the research is to be carried out (including knowledge of the particular processes being studied). Therefore, courses in the following areas are suggested: oceanography (biological, chemical, geological, or physical, depending upon field or research), marine optics, limnology, hydrology, electromagnetic radiation in the atmosphere, physics (optics, electromagnetic radiation, etc.), remote sensing applications in oceanography, computer science, mathematics, statistics, and remote sensing instrumentation.

Panel members:

John Estes, University of California, Santa Barbara
Kenji Nishioka, NASA Ames Research Center
Robert Wrigley, NASA Ames Research Center

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Conference Closing Ceremony

The following summaries were presented by persons who attended the conference and who agreed to provide a short description of their reaction to the activities that transpired and their thoughts for future CORSE activities.

CHARLES NELSON, Chico State University "As I listened to the first couple days' speakers, I became discouraged and lost as far as the discussion of digitizing and related subjects. I also was kind of jealous, I think, because we don't have those facilities. We are a small school, and we just can't afford digitizing and computer equipment at this time. After I started complaining, we went to the workshops and I found out that some of these facilities are available to state colleges if they have a computer system and some of the programs can be re-written to fit their particular computer system, so I became a little bit more encouraged. The rest of this is going to be just a series of little thoughts that I've had of things that I expected and things that I didn't get.

One of the shortcomings I thought was the imagery availability. I thought that I could find out more about how to obtain a lot of things, particularly thermal infrared and SLAR images. I've been trying to locate sources of such data but I still haven't succeeded. I have names and addresses of source agencies, particularly in the state of California, that I hand out to students to tell them if they're interested say, within the Coast ranges, "Here are some of the source areas, here's how you can get hold of the indexes" or you can come to me and I have most of the indexes and I can help fill out order forms so they can order their own imagery. I'm hoping that maybe something like this can be added to the Proceedings because it would surely help me, particularly in the SLAR, the thermal, etc., etc.

Another idea I came to the conference with is having NASA help me, and I've found out that NASA can't necessarily help me. I have to take care of myself. So I guess that's when we start working together and I've started interacting with other people (the people from Oregon say they're having troubles with getting imagery). I think that that's one of the big things that I've learned is the location of other data sources--sources that I thought I knew most of them, but I don't. And so that's been one really big advantage.

I've also found out about the equipment that others have that I don't have. They seem to be amicable to me coming and using some of their equipment, so I'm going to do it. And if they get tired of me, I'm going to do it anyway. I'm going to press them as far as I can go. I do remember sending one student to Ames to use copy equipment to obtain imagery of a fire that had occurred in Southern California--he was doing a report--but I didn't know that this imagery is available for most of the United States. There's other things like audiovisual materials, cheaper ways of doing things if you can't afford the imagery you can gain copies by offsetting some of this stuff. You lose a little quality, but it's still worth it. Ozalid overlays are other ways of getting a little bit better imagery.

Probably one of the best things about the whole week was the interaction with the "greats" in the field like all the people I always read about and I wonder what they're really like. Some of them have ideas that are a little different that I had in mind. Some of them are just what I expected, but being able to interact with them and tell them what I want or ask them what they've been doing, I've got some very, very positive results out of that.

I now have information for sending students on to other universities. Our program at this time has only one or two courses offered in remote sensing, but now I can recommend, for example, that interested students who want training in digitizing go to CSU (Colorado State University). So that's been really good. And myself, if I'm going to go on for a Ph.D., I'm going to have to find out where I want to go so that's been really good for me.

Social interaction, well, I'm getting tired, I'm glad I'm going home. It's been a few rough nights, I'll tell you.

Another shortcoming that I've had, that I've felt from this Conference is jobs. Where can I send my students for jobs? If I want a job, where can I go? The budget's coming out in another week. I was hoping to find a few answers. I hear a lot of that sort of discussion that remote sensing is a job and that jobs are available. I've asked a few people. I guess they're just not there unless you know someone or unless you go to the right school or something. I guess that's more homework that I'm going to have to do. I'm going to have to seek out these state agencies. I'm going to have to try to get my students internships. Perhaps, this is another suggestion, in the Brown Wrapper, maybe there's space in the newsletter for job availability, jobs that are being offered within the field of remote sensing.

The field trip. I think that it would have been helpful to have a field trip like the one at Santa Maria, where you get people using the imagery out in the field. Perhaps the field trip, if we're at Ames again, could visit the San Andreas fault. We could use satellite and other imagery of San Francisco that's been printed in color (false color composite). The field trip could visit a site along the fault and include looking at cultural features, such as the salt ponds and the South Bay. Such a field trip could be quite valuable for a future Conference of Remote Sensing Educators.

Workshops. Workshops were probably the most successful, I thought. Starting to interact, I wasn't quite as nervous after I found that other people were having similar problems. At first I thought it was just me, I thought, well, you're really weird. These people are talking about a lot of things that you don't understand, that you've never heard of. I started interacting and finding out that a lot of them are having the same problems I am. The workshops helped get a lot of that out for discussion. There's a lot of the workshop discussions that I missed that I really want to pick up in the Proceedings.

The Ames tour was fantastic for me. I can understand the technology a lot better now. I hope to bring my students down here in the future. We're located a little closer than a lot of universities, but I guess that's to our advantage."

PAULA KREBS, University of Alaska "We have been asked to address three particular questions. One of them was, what did we expect when we came down here, and the second one was, what did we find. Thinking about this, I suppose one could say if you expect nothing in particular when you start off, then you're not disappointed when you get here. Which means then that we can dispense with the first two questions and move on to the third one--an overview statement. Along these lines, I would say that we all came down here with certain feelings, and I've heard one of my colleagues make the statement, even today, that, we came down here with the thoughts of we can get something for free, and NASA probably had the thoughts, we can get something for almost free, and indeed we've been making our wishes known, we have been stating what some of our desires are, what the needs are and making a distinction between those.

I think that one of the major contributions that this series of meetings has given to each one of us is the opportunity to establish and renew acquaintences that we have not had the opportunity to do so before or within the relatively recent period of time. This is especially true for me where I find myself separated by geographic distance as well as increasing phone-rate costs. Along the lines of sharing our own experiences with other people, the problems that we have and how others may have addressed the same problem and came back with an answer, has helped me to grow, has broadened a particular base that I have to rely on when I interact with other people on my own campus or in other agencies with which I'm dealing. I think perhaps this is one of the most critical things, that it does give us a format to exchange ideas, and each one of us has been very open in a lot of our comments.

As the week progressed, instead of just a polite smile when you met someone the first evening that you came in, it is now that you feel very free when you go in for a meal and you can fluctuate among many different tables when you sit down. The courses of conversation have ranged anywhere from a very detailed study of meteorology down to a discussion of lichens. Even at one point in the workshop this morning we were sort of characterizing some of ourselves as being re-treaded when we came down here because we had gone through a certain sequence of ideas and we suddenly found ourselves absorbing so much more.

To be very specific on a lot of the comments, I hope NASA was listening. We made some very specific statements as to what we feel we need to upgrade, improve, expand, the concept of education relating to various aspects of remote sensing, be it in geology, in forestry, in range, in land-use management, in urban planning, the whole sequence. We talked about applications orientation, in other words. We've also talked about technology development. We talked about the development of new sensor systems and how there is a gap between when those systems are being developed, the expectations of the type of data products that we are going to get from that to the hands of us who have to relate this to our students, who have to interact with some of the rest of us. I think that this perhaps has been one of the most important suggestions that we could have made, that is, help us in terms of the current state-of-the-art, in terms of the developmental system sensor packages that we are looking at in the future.

With all of this, I think that we should keep in mind, we've all had some disappointments that have come out of this. To correct those disappointments for the next time this comes around, we are obligated to make a very definitive statement as to what we need, what we want next time. In terms of a series of workshops, I think the best ones that we've had have been in terms of the discipline-oriented workshops where those of us have common problems or points that we can discuss among ourselves of new approaches to things that perhaps one of us has not tried but others have had experience and as a result we can improve our own approaches. With this we can lead very definitively into what is needed to provide the necessary information for the effective dimensions that the community colleges wish to take, the effective dimensions as far as four-year schools are concerned on undergraduate education, as far as graduate education, this also applies. So I think that the ball we've carried so far, we can't drop at this point. We're going to have to continue on. And I'll guarantee you one thing, Robin and Chuck and all the others we've interacted with, I'm going to be pestering them via the what is it, 15¢ stamp now, via the phone lines, whenever I run into a particular problem that I feel that they can perhaps point me in the right direction. I'm going to be adamant about this, and I'll probably have a very good reputation of being a pest before this whole thing is over with. I don't know about the rest of you, but at least it has opened up a lot of new dimensions that we can begin to try and if we do it often enough, we will probably find that we're going to be heard, and heard fairly clearly. I don't wish to really say much more because I think you have said it this week. I hope others have been listening. Thank you."

JOSEPH LINTZ, University of Nevada "Last Saturday and Sunday I had two very delightful days. A neighbor of mine has a 26-foot Erikson sailboat and he asked me to crew for him on the boat so we went up to Lake Tahoe. He belongs to the Tahoe Yacht Club, and there was a gale on Saturday that was blowing about 50 miles an hour. We went out double reefed and no jib and for some reason or another we were 5 minutes late crossing the starting line and we were about 30 minutes late at the end. The next day the wind was very light, the first hour we almost drifted, the fleet pretty good, about 40 boats, I guess, and it was very dull for at least the first 40 minutes of the race and then the breeze freshened up and it got continually stronger though it never got to 50, so we did not reef. We played with a bunch of sails and the ship was way over on it's side, and suddenly he yelled at me, "Get up on the windward side, get on the windward side, your're on this crew because of your weight!" And I looked at the other crew members who weighed considerably less than I did and I said it was very nice to know why I was being asked to serve on this crew. Well, when Robin asked me to speak, I looked into the mirror to see if it was my weight again that got me this anchorman slot or what, and it turns out it's perspective and seniority. Well, you're familiar with perspective. You had it well-defined by Ida Hoos the other night in a very charming and entertaining talk, and I want to give you some perspectives as well that I think fit with this conference.

This CORSE-78, I think, has to be equated with some other things that are going on in NASA. I think that the planning stages for this must have been some time last winter perhaps, and it takes that long to set something up like this. But while that was going on, planning in Washington was going on in a totally different situation that definitely overlaps. This was referred to on some of the papers Tuesday and this is the Isetap program coming out from the White House. The reference was made to this document which is just off the press, you might say, issued by Governor Lamm and his task force of Colorado which is an identification of Landsat utilization by various state governments. What we saw the first part of the week, and I think we've gotten away from it, was a rather strong emphasis on working to get Landsat imagery more widely used at the state and local government agencies, so I felt I was in a classic military pincers movement with the Isetap data coming out last week via Washington and Denver and the people that are going to have to do the job to interface with the state governments being here and that is the universities.

Now there has been a dicotomy here, very obviously, because as the week has gone on there has been less emphasis on the aspect of getting the state governments involved in the utilization of Landsat. We do have, I think, two ways to go here and as educators, we need to be interested and need to have the availability and the capability of performing both. And I think that we should

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be looking in terms, those of us that are in a position to do so, in involving state and local government with Landsat possibilities and potentials to give short courses as needed. Now I recognize that there are many present who are not yet in this position, but those who are, I think will have to take the time and I hope they'll want to take the time to do this because it is important.

What's the end run on all this? The end run on all this has to be Congress and has to be continued support for Landsat programs, has to be availability of money, continuing availability for money. One of the points raised by the states in the survey that is documented here is, do we have a commitment from NASA that the Landsat satellites will be a continuing thing. There is worry whether we should crank up and get involved in hiring a bunch of people and utilizing Landsat as fully as we might, if after C or D the program terminates, and that's a very valid point. I think that NASA is in the process of making a commitment to the state governments. They're going to have to give if they want to see Landsat imagery and data more widely used.

The other side of the coin is that most of us are involved in university teaching, and we are concerned in either the junior college level, the 4-year college or the university level with putting out people who will become professionals, who will be perhaps disciplinary-oriented, and then a small group, one or two schools will, of course, be turning out Ph.D's in remote sensing. Speaking for my own school, I have no desire to get into that business but remote sensing to me, Landsat and other things, is another tool of the trade. It is effective mapping. You can see more, you can get more information, and it is cost effective. So, it is cost effectiveness, of course, that is going to be as accountants term the bottom line and I think this is one of the reasons we have to pay so much attention to what we're doing here is that these technologies appear to be more efficient. Our preliminary experience based on the experience of 5 or 6 years since Landsat-1 went up and the experience with airborne data, whether it be infrared, radar, or what have you, tends to support this. So, I think that as educators we have a multiplicity and some of us are going to be good at one thing and some of us are going to be good at the other thing and one or two are going to go off and do extensive sorts of research, but there are plenty of opportunities in remote sensing for all of us to participate at various levels. We will all, of course, be trying to do a quality job at whatever level we see as an appropriate goal for our own talents within the limitations of the school in which we work.

A very strong point, and Paula has already mentioned this and I think Chuck too, I'm going to put it in slightly different terms, is communication. I think the biggest gain from this conference has been the avenues of communication that have been opened here. I think, I've sensed, and I said it even Tuesday afternoon having arrived Tuesday morning and missed Monday, I feel a sense of momentum in the participants and the people like myself who did not assist in the putting on of the conference and the planning and the execution. I do feel a sense of momemtum. There is an enthusiasm, there is an interest here that is going to be carried back; I think Chuck just gave us a very strong indication of an individual that has been quite turned on by this. Strong communication, as I see it, has taken four forms. We heard some good papers in the plenary sessions on Monday and Tuesday, I'm sorry I missed the Monday ones, but there were some quite good papers. This morning I heard, I presume a graduate student say that he thought they were too long, that that should have been telescoped into one day, and that's a matter of detail, that's second level organization sort of things. I was pleased that the working groups were small enough that there was full interchange among the participants and that we also had interface with people from Ames and the people from Ames were available and did move around among the groups.

I think there was a very important day or two, the Wednesday and Thursday activities, that allowed for these discussions. We had a selection which was magnificent, heavens, you remember multiple-choice questions when you were taking exams, and I like to give my students optional questions on exams so that they have a little freedom to show off what they know. So, by having more sessions than we can go to we could follow up our own inclinations and I think this was an excellent approach to work out over the informal sessions. And then still more informal and also referred to was the discussion that occurred at the meal tables and I think this was very important.

My third point of communication lies in the future and that is the Brown Wrapper. I think the dialogue (or the multilogue because it's more than two of us talking), that is established here needs to be perpetuated, and I think this momemtum can be maintained. It has been generated here and it can be maintained and I think the Brown Wrapper is an effective medium to do this. However, the Brown Wrapper will not succeed because Robin Welch sits down at a typewriter once a month and once a quarter, or whatever, and types out 4, 2, 3, 20 pages of input material. It's up to all of us to give input to the Brown Wrapper and the Brown Wrapper will succeed only to the extent that those of us here and others that we tell about will have interesting things to say that can come in. Now who is to decide what's interesting? I have a tendency to say, I enjoy doing that but that's a person experience and I'm not going to share it. That's a stinking, no good attitude and I'm not going to call it selfish--that's a bad reflection on me--but I think somebody other than you should make the decision as to what you have done is worthy of sharing, in other words a little objectivity. Others of us perhaps are quite egotistical in everything that we do. Every time we take a breath it's got to be recorded, like the hen that lays the egg and cackles about it and the fish that lays 60 million eggs and swims away silently.

Lastly, is something that perhaps is not generally aware here, during the week Jack Estes invited me to become a member to represent Nevada on the Remote Sensing Science Council and this is an organization that apparently meets twice a year. They had 3 meetings in 4 nights so they've been very busy all week, and I sat in with them for the first time last night and I'm properly impressed because this is a steering and a guidance group for future CORSE sessions. And I think that the Remote Sensing Science Council with Jack Estes in the chair will be in a position to be concerned about the problems that all of us have looked at, give them a definition, work with Robin and Chuck and the others at Ames, and I think you will see many of their inputs in the Brown Wrapper. I think that's going to be a good source of information for the Brown Wrapper. It's a fairly well-structured committee. They have their committee assignments where 3 or 4 people serve on each committee. It's a committee with one representative per state or perhaps two from California.

Well so much for communication. We identified multiple problems this week and we discussed them on every hand and proactically from every aspect and phase. I don't know how to put these in any priority, but one of the problems that we identified and talked about is that we have in our participants an extremely diverse group. We have people from university centers which have been perhaps heavily funded on research grants and have extensive equipment, and I think I represent a middle group which has been funded and has a limited amount of equipment and there are the schools that might consider themselves the have nots because if they come up with a stereoscope or two they probably busted the month's equipment funding.

Many came looking for bucks NASA was going to be handing out, and I think that was erroneous. Paula mentioned that we came to this conference for many different reasons and we came with many different emotions. As educators, we seek to give our students, our normal students, the people who are going to be active tomorrow, the best possible course that we can and again I think this depends on the atmosphere and the environment of the school that we come from. I think we have received assurance from NASA that they will support our activities. I very definitely have a feeling that we will have support. I have been assured of some support on a limited scope project that I expect to run off probably in late October, or early November, and I've been assured, yes, we will do this, we think this is great. You be the spear point, you be the honcho, you get the wheels rolling and we will be there, providing you keep us informed and coordinated, but I have an oral commitment, nothing in writing, that they are interested in this.

Support may come not in the form of expensive analytical apparatus or computers or state-of-the-art devices. I don't think it should necessarily. We're not all talking here about investigative research. We are educating, we are training, we are teaching and you can illustrate principles with less than the most expensive equipment. Obviously, somebody can cut the lawn with a hand sickle or a push mower, or a power mower--we have a tendency to always want the power mower. I don't want to spend my afternoon with a sickle going around and cutting it by hand any more than you do but one can do a credible job with a push mower at a modest investment. What we'd all like and I think one of the most importabt things that we would like to get support on is more data.

We would like for our students to have a bigger library, maybe not teaching aids but we need more IR, we need more SLAR imagery. We need more Landsat imagery and this is still fairly expensive and I would think from the discussions that we can get our hands on this material at little cost. We can beat the cost of the EROS center for example, where some of these selected scenes can be lithographed in 50 or 60 thousand copies and the cost is down to a nickel. Quality isn't the same as a photographic reproduction, but it's good enough for many teaching purposes. Again, if you're having a hard copy, photographic copy, you're talking again about a power lawnmower. I'm talking about a push mower--we can make do. This morning in the Geology session Floyd Sabins showed us multilithed material that had been run on a multilith with a screen, and for preliminary, undergraduate interpretation it was very, very good, some of it was fine, other copies were of a little less quality--there was variation in what he showed us, but that was all within an acceptable quality range for teaching purposes. So I think we're here to tell NASA that this is one of our high priorities to have accessibility and to help us in obtaining some of this material, and this by NASA's standards, is not particularly expensive, particularly if they go to lithography of selected scenes.

And lastly, I have a tendency to feel a little bit like the honoree at a Dean Martin roast, I guess, although we haven't been name-calling or anything, but I really would pay tribute to the people who have put this conference on for us, and I think we owe them a big debt. I think personally it has been an outstanding conference. There obviously has been a lot of thought given to it from the planning point of view, as well as the implementation. I don't think that you could have chosen a more delightful site in late June than the Stanford campus. The Stanford people have been, as far as I can see, just really outstanding in assisting Ames personnel in carrying this off. Let me give you one illustration. This morning at 8:40 when the Geology session started, the chairman said, "Gee, it would be nice, I have some overhead projector things--there's no overhead projector in the room." By 8:50 there was a working overhead projector in the room, and I just think that's pretty great that the Stanford audiovisual people have that type of flexibility. And let me compliment the Ames people too because I don't think on Tuesday morning they knew that Thursday afternoon we were going to be at Ames. That tour was thrown together (the word when I was at Manned Spacecraft Center in the 60's was "clooged" together) in a very quick order. Well, you've heard tributes paid to the tour and I share the sentiment on those comments. So the flexibility that was shown I think we have to pay tribute to. The food service has been good, this is a beautiful auditorium, our quarters over at Tressider Hall were adequate, and on behalf of the participants, if I may assume a prerogative here, Robin, Chuck, and Dale and others, we thank you very much for the trouble that you've gone to to make it possible for this meeting. We've spoken to you and we've listened to you and I think you've achieved your objectives."

BOB COLWELL: University of California, Berkeley. "We can safely presume that it is the objective of virtually everyone here, as an instructor in remote sensing, to give the best possible course in remote sensing. So let me quickly highlight a few of the things that I think we have learned here with respect to each of several ingredients that go into the making of a good remote sensing course at the college or university level.

First, we need to consider whether it is to be an appreciation-type course in which the popular 'gee-whiz' kind of presentation may be appropriate, or whether it is to be a basic remote sensing course for the professionals, or perhaps a more advanced course. Since most of us are teaching a basic course for professionals, I will restrict my comments to the teaching of that type of course.

Obviously the first ingredient is the instructor. We've agreed here this week, I think, that the instructor must be neither ignorant nor apathetic (to refer once more to the story I told at our opening session), but in addition it is probable that many of us suffer from never having been given any formal instruction, ourselves, in how to teach. This has always impressed me as being rather peculiar. For a person to be considered qualified to teach in an elementary school or a high school, he first must have taken several education courses, i.e., courses in how to teach. But because the typical university- or college-level instructor holds a Ph.D. degree, or some other kind of advanced degree, it is usually presumed that he knows how to teach, and how to do so effectively. This may not be true in each of several aspects of teaching. For example, do you and I as instructors know how to perform properly some of the most mundane tasks that govern an instructor's effectiveness? Do we know how to write on a blackboard without the chalk squeeking, or how to get out of the way so that a student can see what we have written? Or do we realize the importance of taking a moment to look at what we have written before erasing it, to be sure we have made no mistakes? Do we know how to give fair and suitably comprehensive exams, or how to respond to legitimate questions from students? Perhaps so, and perhaps not. I submit that most of us here have never been told how to perform these fundamental tasks of teaching, and I am happy about the interchange we have had this week in our various Workshop sessions relative to most of these topics that bear on our effectiveness as instructors.

How about the teaching assistant? We've had little talk about him here, at least in the Workshop sessions that I have attended. Therefore, let me emphasize that it can be mighty important that the teaching assistant be given a high degree of credibility in the eyes of the students--and the earlier in the course that we, as instructors can help accomplish this, the better. We automatically use a teaching assistant for most of the routine tasks. For example, we ask him to hand out the photos, and the instruction sheets, and the pencils; we have him make sure that students sign up for stereoscopes by the numbers, etc. But surely we can and should do more to establish the teaching assistant, in the eyes of the students, as a valuable and knowledgeable resource. I tell my teaching assistant a week or two before the course if not earlier: 'I would like for you to give one of the class lectures, some time during the first two weeks of the course, on any remote sensing-related topic of your choosing.' Invariably, the teaching assistant does a good job, in my experience, and thereby does much to establish a high degree of credibility--something which can go a long way toward making a successful course.

We have had many comments here at CORSE-78 about the importance of photographs and other forms of imagery as factors in the offering of a remote sensing course. I personally favor the use of only a limited number of photos, selected in such a way that virtually all of the laboratory exercises can be performed on this one set of photos. In this way, the instructor can keep the class together, making sure that everybody is doing the same phases of the laboratory problem at the same time, and doing them correctly. Then later, this use of a limited number of photos facilitates the giving of an accurate "school solution" to each phase of the work. Still later, at the end of the course, it may be feasible from the financial standpoint, to allow each student to retain this small set of photos, for further reference when he gets out in the real world. In a basic remote sensing course for professionals, such as we are attempting to deal with in this discussion, it also is important, of course, to expose the students to many other imagery examples. For example, it is highly desirable, early in the course, to show lantern slide examples both of areas where the students know what the situation is, hopefully because of previous experience in the area, and also of other areas--with a view to broadening their horizons.

How about the textbook? As with the teaching assistant, it is important to give the textbook a high degree of credibility in the eyes of the students. As the instructor you might be well advised to tell the students early in the course that you consider the textbook that is being used in the course is of high quality (if indeed it is) and that you want each student to study carefully all of its image examples, as well as its textual material. You might further tell them that you do not intend to lecture at any great length about the various topics that are covered in the textbook, and that instead you will be discussing other remote sensing topics that are complementary to material covered in the textbook.

Then what should the instructor cover in the lecture sessions? Part of the answer is provided if you agree with me that it is desirable to give the students the maximum amount of time in the laboratory to work with remote sensing imagery, instead of hearing lectures during laboratory periods about that imagery. Therefore, instead of your taking the first hour or so in each laboratory to lecture on how the students are to do the laboratory problem, you might cover that material in the lecture hour that immediately precedes the laboratory period. The use of guest lecturers is an opportunity that none of us should miss; it is truly refreshing from the student's standpoint and can be reassuring to hear some "Outlander" speaking the same language as the regular instructor has been speaking in his lectures.

What is the appropriate workload for students, as imposed by a course in remote sensing? We all know that each unit of credit should represent an average of three hours of work per week throughout the course, whether this results from one hour of lecture plus two hours of related preparation, per unit, or one three-hour lab per unit. If we, as instructors, are not careful, our students may find that they do not need to put in this amount of time--as indeed they should. One flagrant and hopefully atypical example of too much permissiveness on the part of instructors resulting in the making of a sham of course work and the associated units of credit, occurred at the Berkeley campus of the University of California during the decade of the dissidents (the '60's). According to official reports, there were many students during that time who received 35 to 40 units of credit in a single quarter, one way or another--and one student got an unbelievable 55 units of credit at that once elite educational institution during this "anything goes" period!

Now as for the equipment that's needed, we have indicated that we surely could do better with more equipment, and indeed we could. But be mindful also that many of these trainees of yours are going to go out there to the ranger's shack or the forward area, one place or another, where about all they could take with them anyway is a pocket stereoscope, the photos, a pencil and maybe some kind of a little measuring device and some acetate overlays. So don't presume that the time is wasted if they have for use in this basic course fairly limited equipment as long as one way or another they get exposed later on to the other kinds of devices, either by demonstration, field trips, or whatever. The field trips themselves, if feasible, certainly are a strong plus especially after the students have puzzled over what the attributes of an area might be as seen on the imagery and then get into the field with imagery in hand and find out for sure whether they were right or wrong about it.

I think I would be remiss if I didn't mention something about examinations, and here forgive me for imposing my own particular idea. I spend approximately two hours each time I develop a one-hour exam. I also attempt to give a good overview, during a lecture period immediately prior to the exam, of what I think were the most important things covered in the course since the last previous exam, including some of the critical technical points so that almost never do I have a student coming up when the exam is given to find out what kind of a trick question this was. He usually has been exposed to what I thought was important and I think he's entitled to that. I personally always have, and always will, grade every question on every exam that I ever give. Now maybe this is where I'm cutting the TA out of some fun, but I reserve that for myself, and I thoroughly enjoy, time-consuming though it is, grading my own exams. It's one of the better ways to find out whether I'm getting the point across. If one or two students miss a question, then shame on them--but if everybody misses it, shame on me. And I told my students as recently as about three weeks ago, if you think that was a lousy job of presenting that material as evidenced by the fact that none of you got the answer, just think what a lousy job I must have done 30 or 40 years ago when I was first teaching this stuff, and what I must have learned in the meantime through the grading of exams. I also tell them perhaps there is greater justice if the instructor grades these exams, because he is the guy who gave you the information in the first place, and he can best exercise all the checks and balances, to give you the best justice he can. I also tell them that if they still find some injustices, to relax. After all, as instructors, we're trying to train you for real life, and you probably won't get as fair a shake in the future as you got in this particular case. So, I think these exams are exceedingly important.

I think that we also need to consider whether teaching can be augmented with research work that is going on. Can we put these students on the payroll? In this way our research work can fill in some big gaps.

And finally, what I tell my students as we conclude a course is, if I don't hear from you people in the next few years, I will presume this course has been a failure, at least from your standpoint. I hope that as you get out there in the field you'll recognize there's a lot of things we should have covered and didn't, and you presume that maybe I either know how to cover a technical point or can find somebody that does know how, at which point you should get in touch with me, and if this means that you come down here and use our equipment or we work with you a bit to solve a problem or use the reference materials or whatever, find--this is the program at its best. Another opportunity that is related to student development is in the placement of these individuals in summer jobs and in jobs following graduation. To help them in this regard, it's quite important, I think, for each of us as instructors to know as best we can, not just what the grades were of these students, but also some of their other attributes. Can you evaluate the whole man?

The last point I would mention is with reference to equipment because I believe that there is one item which is not too expensive but highly important and I take the tribute here from Ellis Rabin who is the only photo interpreter I know who also has his Ph.D. in optometry, so he knows all about vision. He says the biggest deficiency is in lighting. You may have images taken with wonderful devices, and you also may have pretty good stereoscopes to look at them with. But now you get down and obscure the light with your head as you look through the stereoscope. If you have nothing more than a gooseneck lamp to improve the lighting, this would help quite a bit. He can tell you that the diameter of the pupil of the eye should be roughly 4-mm when you have maximum visual acuity, and he certainly has convinced me that I can see a lot more with optimum lighting than otherwise.

This leads then to the final little story I would tell which I hope you consider apropos here. It all relates to lighting. It seems that it was proposed in the local church that a chandelier be bought for the church. Well, this was a matter of sufficient moment that a special meeting was called of the session, or governing board of the church. Throughout the discussion most of the session members seemed to be much in favor of this purchase. We previously were talking about this matter of ignorance and apathy so this episode serves to illustrate the point. It happens that the clerk of the session was the primary one speaking out against the proposed purchase of a chandelier, and very vigorously so; hence, he couldn't be considered apathetic; but was he knowledgeable? By the time the session's meeting had adjourned, two hours later, a decision still hadn't been arrived at, primarily because the clerk of the session had been speaking up in so much opposition. Thereupon one of the distraught members of the session went to him and said, 'Clerk, I would like for you to tell me straight out, once and for all, why you are so unalterably opposed to our buying a chandelier for this church.' The clerk thought it over a bit and then said, 'Well, there really are three reasons. In the first place, as you know, I have to take the minutes of this meeting and I don't know how to spell chandelier--in the second place, I'm virtually certain that even if we went ahead and bought one we couldn't find anyone in the congregation who could play it; and in the third place, what this church needs more than anything else is better overhead lighting.

Now, I think that that relates somewhat to how much ignorance or apathy an instructor may bring to his course work. But does it apply to us? If Joe Lintz hadn't done it, I certainly would have to praise the quality of both the program and the participants at this five-day conference. Like Joe, I am among those that are much impressed by the quality of the experience we've had here and I share his enthusiasm for the kudos that have been given to Robin Welch and his associates for the conduct of this meeting. Thank you very much."

MERRILL RIDD, University of Utah: "I think someone ought to speak up as an unsolicited respondent. I'll make this very brief. There's been a lot of talk here this week and I, for one, have benefited much from it and I think we all have. There have been some pluses and some minuses, some aggravations, some concerns and some name-calling, and all kinds of things going on here, and I think it's all been healthy. I'd like to summarize my feelings, and I think this may summarize the feelings of a good many people I've talked to by the following. With all that we might like to think, the WRAP Program does have a charter, but it does also have some limitations. We'd like to think that it hasn't any unlimited fund and an unlimited mission, but the fact is, it does, and that was very well expressed by Wayne Mooneyhan this morning in our session and has been by other people along the way. On the other hand, we as educators do have our needs. Now, if the NASA/WRAP objectives and mission don't very well match our particular needs, we can hardly hold NASA and WRAP responsible for that. However, I do think there are a couple of things that we do have a right to expect, and I just pass this on for what it's worth. I believe we do have a right to expect as educators interested in remote sensing, interested in NASA, interested in promoting the state-of-the-art and science, we do have a right, I think, to expect two things. One of them is a matter of continuing communication for which this particular session has been most valuable and stimulating. The second thing I think we have a right to expect as educators interested in those things is a right to expect that when NASA and WRAP and its agencies or arms move into a state in a local area to transfer technology, which is their mission as well explained by Wayne and by the other representatives of the WRAP program, that we have the right to expect that they will stimulate, that they will encourage that local agency--state, federal, local, whatever--to be aware of and interested in soliciting the support of the local university to build up that university and to suggest that there be a close interaction and tie between the two so that NASA's arm becomes stronger by reason of that association with the local university. Now, there's a third thing that I'd like to think that we had the right to expect, but I think all we can do is beg from the WRAP program, or from NASA through some instrumentation, and that is an access to aids, teaching aids of various sorts, which has been discussed many, many times today. I don't believe we have necessarily a right to expect that; I do believe, however, that it's such an overwhelming undercurrent of concern and desire on the part of all the people that I've talked to here, and it's come out of every session I've seen that it certainly would be a very welcomed kind of activity however limited that might necessarily be for NASA and WRAP to promote to assist those local schools with the better teaching of their programs. On the other hand, we as educators have one responsibility, and that is to be first-rate teachers and first-rate researchers and to work in our own way with local agencies in the betterment of our students and the local agencies, and NASA can become a very instrumental part of that. I'm almost wound down. The last think I'd like to say is that I see this thing very definitely as a triangle on which we have NASA/WRAP at this end, we have a state agency or local agency at that end, and out here on another apex in the triangle is the university. I'd like to see a total cooperative effort between all three of those units, and I think NASA can help to promote that. I think the Remote Sensing Science Council is set up to accomplish that--I'd like to think that that is our mission. As a member of that Council, I would like to promote that and see to it that the local univerity is definitely on that pipeline, that it's not just NASA at this end and the agency at that end. I'm sure that that is the objective of the WRAP people, but sometimes I think it can be lost sight of, so I would simply leave that as a final note of encouragement along with the word 'cooperation.' I think that's what it all boils down to, and I'd like to extend a vote of thanks to Robin personally who has done a fantastic job of putting this program together along with the aid of many, many people, notably Jack Estes and Dale Lumb and some others that I'm probably not even aware of, but I think they've done a great job and I'd like to have us extend a vote of great thanks to Robin for a tremendous job well done."

ROBIN WELCH, Chairman, CORSE-78: "Thank you ladies and gentlemen. We didn't organize this event alone, as I said on the first day. We can all take credit for this Conference because as we began to talk to various individuals it appeared to be an idea whose time had come. A general comment seemed to be, 'Why haven't we done this sooner, let's do it!' I think we owe a great vote of thanks to Stanford University. Dr. Rich is our host for this week, and I want to thank him and all of his staff, and all of the people here at the University who made it a very enjoyable week. The food was great, accommodations were good, better meeting facilities we couldn't ask for. Ray McKee has been in our sound and projection room in the back--he is a Stanford audiovisual specialist--and seldom have I seen anyone that is as great a professional at his job as he is. I'd like to extend my thanks to Ray for being on the spot with some complex equipment that didn't break down, it didn't squeal back at us--everything worked. Unassisted, he set up all these tables for this morning's session. It was an excellent effort. Thank you very much, Ray. We wish also to express our thanks to certain people at Ames who on very short notice arranged for the bus trip to Ames; namely, Mike Donahoe and Garth Hull, who arranged to have the bus available. And, of course, we wish to thank Dale Lumb who made this Conference possible through some very helpful people in his Branch.

In reality, this is the first time that we've really been together with education as our primary interest, not here to learn about the good things that remote sensing will do for us, but find out about the educational problems. I think in any future CORSE meeting we will perhaps continue the same general theme except we'll expand it a bit and bring in some users who can give us their viewpoint on remote sensing teaching and applications, and secondly, we shoul have some training involved with the conference--perhaps part of the sessions could be devoted to some of the new remote sensing systems that you haven't had an opportunity to learn about elsewhere.

I think one of the great benefits from this Conference is that you're not going to be afraid now to pick up the telephone and call another in your own university, your own state, or across the region, and ask for help or perhaps help them solve a problem they have encountered. That is something that is priceless, as far as I'm concerned, and I think that from this week we're going to grow from this experience. We hope to have another conference within a year or two.

I want to express my heartfelt thanks to you people for the nights you worked, the days you worked, and the way you shared concerns and sentiments with us.

APPENDIX

TO: NASA - Attn: Robin Welch, CORSE-78 Coordinator
FROM: J. E. Colcord, University of Washington
DATE: 27 June 1978
RE: NASA's Function in Education

True education is a time-based learning experience of quality not quanitity that requires background fundamentals as a starting point. For remote sensing, I believe these to be mathematics, physics and some other relevant scientific discipline. Instant "experts" via a short-course (a band-aid) do not make a real discipline.

Thus, to help in education NASA could; for the Professional

1. Arrange, thru a qualified University for a 6-8 wk. Fundamental Remote Sensing Course for about 25 faculty, with a stipend and minimum expense allowance. This would be given at various university sites.

2. Award NASA Science Faculty Fellowships in Remote Sensing for faculty to attend (3-9 mo.) at a qualified University of their choice.

3. Award NASA Graduate Student Fellowships for a year's study (at the school of their choice but not more than approx. 4 to any one school in a region).

4. Provide hands-on training experience for qualified faculty/students at operational centers for periods of about 2 weeks.

Resolution:

Whereas the faculty are concerned with education of remote sensing professionals, we recommend that NASA strongly support the following:

1. NASA Faculty R/S Fundamentals Institutes at schools with major R/S teaching efforts for 6 weeks duration.

2. NASA Science Faculty Fellowships at major R/S schools throughout the nation--based on competitive admission--for 3-9 months duration.

3. NASA Graduate Student Fellowships.

4. NASA-sponsored hands-on work internships on advanced state-of-the-art for qualified faculty and graduate students.

For technicians, we recommend a sponsorship of state-of-the-art short courses for 2 to 4 weeks duration.

/s/ Robert J. Schultz
G. T. Benson
C. L. Smith
Bert L. Conrey
Charles E. Glass
Joseph Lintz, Jr.
Cheryl Jaworowski
Kenneth Kolm
Moyle D. Stewart
Ernest Rich
J. Smith
D. C. Walklet
K. Jeyapalan
C. Rosenfeld

The following list of remote sensing courses currently being taught in colleges and universities in the WRAP area was prepared from responses to questionnaires submitted by attendees at CORSE-78 and is limited only to information tabulated from those responses.

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Responses to Faculty Training Questionnaire

Courses Currently Being Taught in WRAP States

State	College or University Reporting	Courses Being Taught and Units		Faculty Person Reporting
		Undergraduate	Graduate	
ALASKA	University of Alaska	GEOS 408 (P)*- Map & Air Photo Interpretation (2) GEOS 422 (P) - Geoscience Applications of Remote Sensing (3) GEOL 493 (P) - Remote Sensing (3) GEOS 304 (S) - Geomorphology (3) GEOS 314 (S) - Structural Geology (3) GEOS 362 (S) - Engineering Geology (3)		P. Jan Cannon
		BIOL 239 (S) - Plant Form and Function (4)		P. V. Krebs
			ALR 693 (P) - Natural Resource Applications of Remote Sensing (3)	
ARIZONA	University of Arizona		Optical Sciences/Systems Engineering 236 (P) - Digital Image Processing Laboratory (3)	R. Schowengerdt
			Physics of Remote Sensing (P) (3)	P. N. Slater
		Agriculture 253 (P) (Open to graduate students also) - Remote Sensing in Agriculture (3)		D. F. Post

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*P = Remote Sensing Primary Subject
S = Remote Sensing Supporting Subject

Courses Currently Being Taught in WRAP States

State	College or University Reporting	Courses Being Taught and Units Undergraduate	Graduate	Faculty Person Reporting
CALIFORNIA	Calif. State University, Los Angeles	None	None	T. D. Best
	Humboldt State University	GEOG 181 (S) - Urban Geography (4) GEOG 190 (S) - Geog for Teachers (4) CARTOG 101 (S) (4) GEOG 196 (S) (4) - Intro to Cartog.		J. S. Leeper
		Remote Sensing of Environment 106 (P) (2) Air Photo Interpretation 106 (P) - Forestry Applications of Low Altitude Photos (4)	Advanced Principles of Remote Sensing 206 (P) (3)	L. Fox III
	Calif. State Polytech. University, Pomona	PHYS GEOG 101 (S) (4) GEOG 310 (P) - Earth from Space (4) GEOG 410 (P) - Photographic Remote Sensing (4) Field Geog 309 (S) (4) GEOG 311 (S) - Cartography (4) Calif. Geog 331 (S) (4) GEOG 103 (P) - Image and Map Interpretation (4)		C. S. Miller
	Calif. State University, Northridge	GEOG 305 (P) - Photo Interpretation (4) GEOG 407 (P) - Remote Sensing		R. M. Newcomb

Courses Currently Being Taught in WRAP States

State	College or University Reporting	Courses Being Taught and Units Undergraduate	Graduate	Faculty Person Reporting
CALIFORNIA (Continued)	University of California at Los Angeles	GEOL 150 (P) - Remote Sensing for Earth Scientists (3)		F. Sabins
	University of Southern California		GEOL 680 (P) (3)	
		Physical Geography (S) (4) World Regional Geography (S) (4) Marine and Coastal Zone Geography (S) (4)		J. W. McDonald
			Computer Graphics Workshop (S) (4)	
	Calif. State College, Bakersfield	Remote Sensing is taught as a supporting subject in Geography, Earth Sciences, Environmental Sciences		W. H. Wake
	Calif. State College, Stanislaus	Urban Geography (S) (3) (also graduate course) Geog of Resource Planning (S) (3) (also graduate course) Geog of Europe (S) (3)		M. H. Aamodt
	Calif. State University, Long Beach	GEOL 331 (S) - Geomorphology (3) GEOL 464 (S) - Geological Oceanography (3) GEOL 570 (P) - Adv. Geomorphology (3)		B. L. Conrey
	University of California, Santa Barbara	GEOG 115A (P) - Geographic Photo Interpretation (4) GEOG 115C (P) - Geographic Remote Sensing Techniques (4)		J. E. Estes
			GEOG 215 (P) - Seminar in Remote Sensing (4)	

Courses Currently Being Taught in WRAP States

State	College or University Reporting	Courses Being Taught and Units		Faculty Person Reporting
		Undergraduate	Graduate	
CALIFORNIA (Cont.)	Calif. Polytechnic State University, San Luis Obispo	GEOG 305 (S) - Political (3) GEOG 309 (S) - California (3) GEOG 310 (S) - Economic (3) GEOG 315 (S) - Urban (3) GEOG 350 (S) - Europe (3)		D. R. Floyd
		AG ENG 345 (P) - Aerial Photogrammetry (3) AG ENG 445 (P) - Remote Sensing (3)		R. Strohman
	Calif. State University, Chico	GEOG 214 (P) - Aerial Photo Interpretation (3)		C. Nelson
	**Sierra College			V. Popp
	University of California, Riverside	Earth Sciences 4 (P) - The Earth from Space GEOG 168 (P) - Remote Sensing of the Environment (Also a graduate course) (4)		L. Bowden
	San Diego	GEOG 587 (P) - Remote Sensing of the Environment (3)	GEOG 687 (P) - Remote Sensing of the Environment (3)	W. Finch, Jr.

**Community College

Courses Currently Being Taught in WRAP States

State	College or University Reporting	Courses Being Taught and Units		Faculty Person Reporting
		Undergraduate	Graduate	
COLORADO	Ft. Lewis College, Durango	GEOL 423 (P) - Photogeology (3) GEOL-ENG 390 (P) - Introduction to Remote Sensing (3) GEOL 401 (S) - Environmental Geology (3)		R. W. Blair
	Colorado State University, Ft. Collins	ER 402 (P) - Principles of Remote Sensing (2) ER 404 (P) - Resource Information Analysis (3) (Also graduate course)		J. A. Smith
			ER 504 (P) - Computer Analysis of Remote Sensing Data (3)	
	University of Denver	Remote Sensing 13-324 (P) (Also graduate course) Introductory Course (5)		R. D. Rudd
	U.S. Air Force Academy	GEOG 382 (P) - Geographic Applications of Imagery Analysis (3)		C. L. Smith
HAWAII	University of Hawaii	GEOG 375 (P) - Intro to Cartography and Photo Interpretation (3)		Sen-dou Chang
		GEOG 470 (P) - Remote Sensing (3) (Also graduate course)		E. Wingert
			GEOG 762 (P) - Research Seminar in Remote Sensing (3)	
IDAHO	University of Idaho	FWR 375 (P) - Aerial Photo Interpretation of Natural Resources (2) FWR 300 (P) - Field Aerial Photo Interpretation (1)		J. Ulliman

Courses Currently Being Taught in WRAP States

State	College or University Reporting	Courses Being Taught and Units		Faculty Person Reporting
		Undergraduate	Graduate	
IDAHO (Cont.)	University of Idaho (Cont.)	FWR 470 (P) - Fundamentals of Remote Sensing (Also graduate course) (3)	FWR 573 (P) - Advanced Aerial Photo Interpretation (2-3) FWR 502 (P) - Remote Sensing Seminar (1)	J. Ulliman
MONTANA	Montana State Univ., Bozeman	GEOG 310 (P) - Aerial Photo Interpretation (3)		J. M. Ashley
	University of Montana, Missoula	FORESTRY 351 (P) - Intro to Photo Interpretation and Remote Sensing (Also graduate course) (4) FORESTRY 450 (P) - Advanced Aerial Photogrammetry (Also graduate course) (3) FORESTRY 451 (P) - Aerial Remote Sensing (Also graduate course) (4) FORESTRY 454 (P) - Advanced Image Analysis (Also graduate course) (3) FORESTRY 499 (P) - Photogrammetry and Remote Sensing Problems (Also graduate course) (1-3) FORESTRY 252 (S) - Plane Surveying (4) FORESTRY 350 (S) - Advanced Surveying (4)		F. L. Gerlach
NEVADA	Mackay School of Mines, Univ. of Nevada, Reno	GEOLOGY 404 - Remote Sensing of Environment (2 separate courses - - same description)	GEOLOGY 604 - Remote Sensing of Environment	J. Lintz

Courses Currently Being Taught in WRAP States

State	College or University Reporting	Courses Being Taught and Units		Faculty Person Reporting
		Undergraduate	Graduate	
NORTH DAKOTA	University of North Dakota	GEOG 275 (P) - Intro to Remote Sensing (3)		W. A. Dando
		GEOG 422 (P) - Graphics and Air Photo Interpretation (3)		
		GEOG 475 (P) - Remote Sensing Application and Analysis (3)		
		ENG 375 (P) - Remote Sensing Systems Engineering		
			GEOG 575 (P) - Seminar in Remote Sensing	
		GEOG 499 (P) - Readings in Remote Sensing (also graduate course) (3)		
			GEOG 599 (P) - Directed Studies in Remote Sensing (3)	

Courses Currently Being Taught in WRAP States

State	College or University Reporting	Courses Being Taught and Units Undergraduate	 Graduate	Faculty Person Reporting
OREGON	Portland State University	GEOL 459 (S) - Geologic Interpretation (3) (Proposed) GEOL 410g (P) - Photogeology (Also graduate course) (3)		G. T. Benson
	Oregon State University	FORESTRY 220 (P) - Aerial Photo Interpretation (3)		D. P. Paine
			FORESTRY 520 (P) - Aerial Photo Mesuration (3)	
		GEOG 413 (P) - Aerial Photo Interpretation (Also graduate course) (3) GEOG 414 (P) - Remote Sensing (Also graduate course) (3)		C. L. Rosenfeld
			GEOG 539 (P) - Terrain Analysis (3)	
		Remote Sensing in Resource Analysis		B. Schrumpf
		CIVIL ENG 362 (P) - Photogrammetry (2) CIVIL ENG 462 (P) - Photo Interpretation (Also graduate course) (2)		R. J. Schultz
			CIVIL ENG 561 (P) - Photogrammetry (2) CIVIL ENG 565 (P) - Analytical Photogrammetry (2)	
		GEOG 413 (P) - Air Photo Interpretation (Also graduate course) (3) GEOG 414 (P) - Remote Sensing (Also graduate course) (3)		J. F. Lahey

Courses Currently Being Taught in WRAP States

State	College or University Reporting	Courses Being Taught and Units		Faculty Person Reporting
		Undergraduate	Graduate	
OREGON (Cont.)	**Treasure Valley Community College, Ontario	Aerial Photogrammetry (P) (3)		K. Knothe
	**Southwestern Oregon Comm. College, Coos Bay	Aerial Photogrammetry (P) (3)		B. Lemoine
SOUTH DAKOTA	South Dakota State Univ., Brookings	Plant Science and Geog 310 (S) - Interpretation of Soils (4)		F. C. Westin
		Geography (P) - Basic Remote Sensing (Also graduate course) (-)		D. Moore
			Geography (P) - Advanced Remote Sensing (-)	
		Elect. Eng. (S) - Communications and Pattern Recognition (-)		
		Geography (S) - Cartography (-)		
		Civil Engineering (P) - Photogrammetry (-)		
	South Dakota School of Mines & Technology		GEOL 599 (P) - Remote Sensing of the Environment (4)	K. E. Kolm
			GEOL 702 (P) - Special Topics in Geology (1-6)	
		GEOL 682 (P) - Geomorphology-Air Photo Interpretation (Also graduate course) (3)		
UTAH	University of Utah	GEOG 347 (P) - Aerial Photo Interpretation (Also graduate course) (4)		C. M. Lee
			GEOG 547 (P) - Advanced Aerial Photo Interpretation (5)	
		GEOG 522 (P) - Land Use Planning (Also graduate course) (4)		

**Community College

Courses Currently Being Taught in WRAP States

State	College or University Reporting	Courses Being Taught and Units		Faculty Person Reporting
		Undergraduate	Graduate	
WASHINGTON	University of Washington		CETC (P) - Remote Sensing of Environment (Civil engineering course) (2)	J. E. Colcord
		Urban Planning 465 (S) - Land Use (Also graduate course) (3) Urban Planning 498D (P) - Urban Analysis with Satellite Data (Also graduate course) (3)		R. D. Shinn
			Urban Planning 508 (P) - Advanced Planning Laboratory (5)	
	Washington State Univ.	Soils/Forestry 316 (S) (1) Soils 415 (S) (3)		B. E. Frazier
WYOMING	University of Wyoming	Geography (P) - Introduction to Air Photo Interpretation (Also graduate course) (3)		L. M. Ostresh

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1 August 1978

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Dear Robin:

I am sorry about the delay in responding to your dunning letters about my CORSE Faculty Needs Questionnaire. I've been on the road and I wanted to take some time and write you an accompanying letter to comment on some things which weren't possible to develop on the 'Needs' form.

Briefly, I enjoyed the conference most for the opportunity to develop a wide range of interdisciplinary contacts but I think the most general benefit accrued to the participants who came with a minimum of remote sensing background. One of our staff members went doubtful but came away seriously discussing the possibility of establishing a joint remote sensing course aimed at the needs of the planning program in Honolulu. However, I believe some of the 'novices' may have come away with a view of academic remote sensing which is at odds with my own conception of the field and it is to this problem that I would like to address the balance of this letter.

I think that the aura that I perceive as the problem arose from two factors. First, the conference organization was structured to answer questions which weren't necessarily important to educators embarking into remote sensing. Secondly, and probably understandably, the conference seemed to revolve around the assumption that NASA is the critical factor in remote sensing education. The latter point was obvious when a formal effort was made to include discussion of the NASA link in every session which often made the interchange of ideas more difficult than necessary. The combination of these two factors made the conference cumbersome. Organized a little differently everything that was accomplished in five days could probably been done in less than three days.

The first point that I feel was overemphasized is the need for a proliferation of remote sensing courses. I see no need in our institution for duplication of coursework in other disciplines but only a need for improving existing courses. Our administration makes it difficult to establish courses in various disciplines with any major degree of overlap. We have no difficulty generating interest among students or acquiring program support but it is very important that remote sensing does not become a 'glossy' tangent in our (or I think any) academic program. In order to have remote sensing become better taught and more integrated in our discipline and university offerings, our department needs three things.

1. Additional faculty time devoted to course and research development. S. D. Chang and I are too thinly spread with our other commitments. We are not able to use the equipment we have as effectively as we would like. I doubt that we will ever (or should ever) become a major center for the development of application or analysis so beyond better use of our computing facilities, we need more staffing rather than massive inputs of equipment which we could not adequately utilize.

2. We need current technical information and sample imagery. We would rather handle our own imagery reproduction for teaching sets so we only need access to some sort of lending library of the newer types of imagery and basic ground truth and technical information. It seems that unless an institution or individual is directly involved with NASA or USGS funded research, there is no channel for systematic acquisition of technical system information beyond the few user courses available. To the present, our best source of LANDSAT and SEASAT information is from a New Zealand physics group whom we sporadically communicate with through the Pacific basin PEACESAT network.

3. We would like to develop more extensive and more appropriate classroom use of digital analysis methodology. Our stumbling blocks are the prohibitive cost of CCT's and not having an in-house programmer of sufficient expertise to generate sophisticated code for small set classroom instruction. Because of running cost we have little anticipated need for the VICAR or LARSYS type of programs. We need help in developing teaching programs that deal with a relatively few pixels at a time, something that will allow students to understand classification not classify massive data blocks.

Is there any way where NASA or some other agency could copy tapes on user supplied tapes on a time available basis? The unit cost of CCT images places them in our university's equipment classification which is at present extremely difficult to tape except for replacement or repair.

The following paragraph is pivotal to two problems discussed at great length at CORSE-78. The primary function of a university is to develop knowledge and to disseminate the latest and best thinking along generally discipline paths. In a more specific sense, I feel it is my primary job as a teaching faculty member to develop in students the ability to think analytically about any topic they encounter within the context of course material.

1. I strongly object to the concept that disciplines exist in a university primarily for vocational reasons. An excellent student is a good employee because he thinks analytically and flexibly not because he has a certain body of technical knowledge. This is an important consideration when the technology is advancing at a rapid enough rate (as it is in remote sensing) to cut distance the substantive fields that employ the technology. As this differential grows, the technology will start to determine what questions are asked. I think that wholesale 'technology transfer' is potentially dangerous in the production of students who think in terms of 'convenient applications' or questions that data is appropriate to approach.

2. The viewpoint that the university is a technical training group can cause conflicts with other state agencies. It is certainly within the realm of university functions to offer specialized training and workshops to establish practical application of remote sensing but it is not any academic department's major function. The university is primarily a developmental group and if NASA promotes strictly technical training and applications in its desire to transfer its 'education' function to the university, conflict of function and interest with other agencies could develop or worsen. For this reason, if NASA decides to pursue the suggestion put forth at one of the Science Council meetings that brief academic seminars be presented by NASA personnel in the WRAP states, the programs should vary depending on local needs. In this case I think state Science Council members could aid in program tailoring to fit different state needs.

I feel that is unfair of me to be critical of conference points without some suggestions. If I were a beginning teacher of remote sensing and were given the opportunity to attend CORSE-79, the following points are some of the things I would like to hear discussed.

1. Before even thinking about problems in teaching remote sensing there must be some degree of 'critical mass' of technical and analytic information. I know it was not intended to make CORSE

just another short course so maybe a series of 10 or 15 good required readings before attendance would be useful. I think that instead of topical presentations aimed at all possible interested parties, question and answer sessions in those areas could fit individual needs more closely as well as stimulate profitable directions. With the abundance of technical experts in remote sensing, sessions with prepared individuals could be exciting and instructive.

2. Applications are important to a field like remote sensing. So instead of a series of panels who tried to give NASA information about their needs, it would be useful to have well organized presentations on proven applications with user groups and accuracy rates and types of analyses that have not proven valuable. This should not be just a group of experts listing their latest research coups but the people who are doing the work.

3. As I mentioned before technical remote sensing is badly outstripping the development of thoughtful problem (disicipline) analysis and philosophy (with a few exceptions like Ida Hoos and others). If the field of remote sensing is not to become so fragmented as to become a set of specialities, the philosophical depth will develop in time. However, much could be done to speed the growth of conceptual thought. The most interesting parts of CORSE 78 to me were discussions related to goals and reasons for teaching. Both the Science Council discussions and debates between Colwell and Colcord brought up provocative points about training and why we are teaching remote sensing. When I thought about specifics that I would have liked to have heard discussed, I came up with the following partial list.

   A. Theoretical Considerations: An image can be treated as a two dimensional data surface; a picture of process; a sample; a result of an atmosphere and system transformation of a data set; and other things including just a pretty picture that lets someone synthesize relationships. Each has implications to the choice and result of the data analysis system.

   B. Underlying Assumptions: We can often be accused of over-zealous promotion of remote sensing--where should it be used and what makes a problem appropriate, surely there must be more than just the availability of imagery?

   C. Decision Making: How are choices made in the analysis technique to be employed; where do the tenets of planning theory or geomorphology enter into deciding how an imaging system or analysis system is designed?

D. Philosophy of Teaching: I approach the teaching of remote sensing as a graphic analysis specialist. My students, in addition to measurement and digital approaches are expected to be able to learn to view tonal gradients, define texture, theorize on whats in the next frame, etc. Every instructor gives students different philosophies. Some discussion of those topics would be of interest.

E. In terms of audience, background, etc., there are many other kinds of remote sensing courses beyond just beginning, intermediate, and advanced. What are the choices in different structuring?

Unfortunately many of the above topics aren't very amenable to a lecture format. But some of those kinds of things would have been useful when I was setting up courses and they remain important to me as I change and adjust my topics and labs to fit whatever my concept of what a university student in remote sensing needs.

Sorry again for the delay in the evaluation form and if this epistle got rather long-winded. You and Nick and the others are to be congratulated for the tremendous amount of work you expended to make CORSE-78 something other than just another gee-whiz workshop. I enjoyed myself and will change my own course by about a quarter as a direct result of the presentation and discussions.

Sincerely,

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16. Abstract

A Conference of Remote Sensing Educators (CORSE-78) was held at Stanford University, June 26-30, 1978, sponsored by NASA Ames Research Center for the purpose of bringing educators together to discuss ways of improving the teaching of remote sensing subjects at colleges and universities in the Western Region of the United States. The Conference format was to have two days of formal papers followed by three days of workshops on various earth resource discipline, image interpretation and data processing concepts. An inventory of existing remote sensing and related subject courses being given in the western regional universities is included.

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